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February 1987

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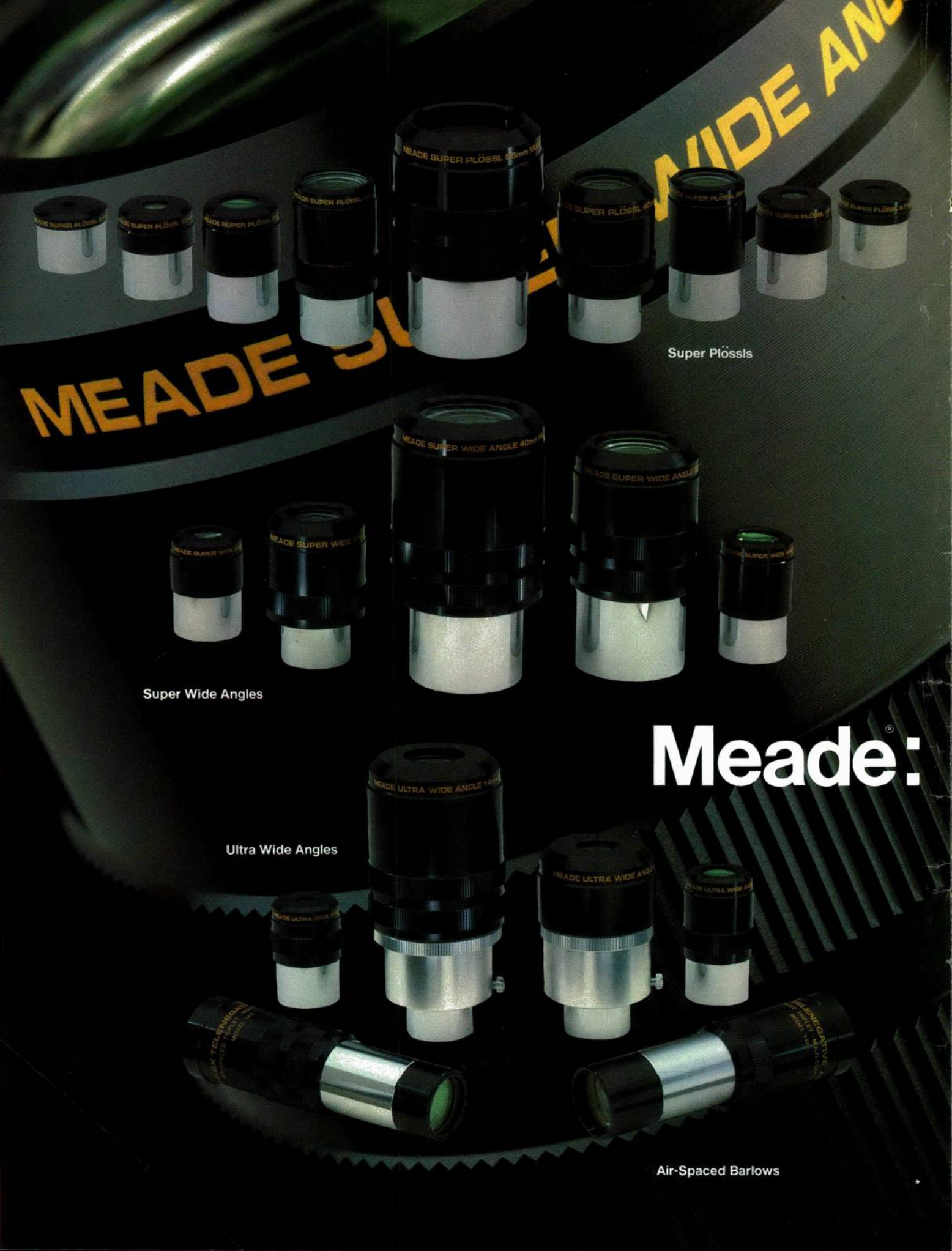
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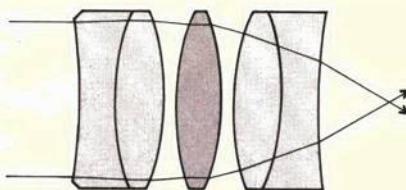
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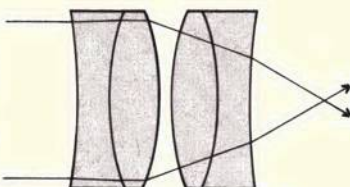
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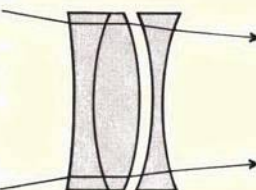
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Meade 5-element Super Plössl design: the central lens element enables significant reductions in chromatic aberration and edge-distortions over other premium Plössl designs.



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Meade Series 4000 Barlows: 3 elements, air-spaced, instead of the standard 2 non-air-spaced elements.

Series 4000 Eyepieces and Barlows

Super Plössl (5-elements)	APPARENT FIELD	BARREL DIA.	PARFOCAL
8.4mm	52°	1 1/4"	Yes
9.7mm	52°	1 1/4"	Yes
12.4mm	52°	1 1/4"	Yes
15mm	52°	1 1/4"	Yes
20mm	52°	1 1/4"	Yes
26mm	52°	1 1/4"	Yes
32mm	52°	1 1/4"	Yes
40mm	44°	1 1/4"	No
56mm	52°	2"	No
Super Wide Angles (6-elements)			
13.8mm	67°	1 1/4"	Yes
18mm	67°	1 1/4"	Yes
24.5mm	67°	1 1/4"	Yes
32mm	67°	2"	No
40mm	67°	2"	No
Ultra Wide Angles (8-elements)			
4.7mm	84°	1 1/4"	Yes
6.7mm	84°	1 1/4"	Yes
8.8mm	84°	1 1/4" & 2"	Yes
14mm	84°	1 1/4" & 2"	No
Barlow Lenses (3-elements, air-spaced)			
#140 2X Telenegative Amplifier	1 1/4"	Yes	
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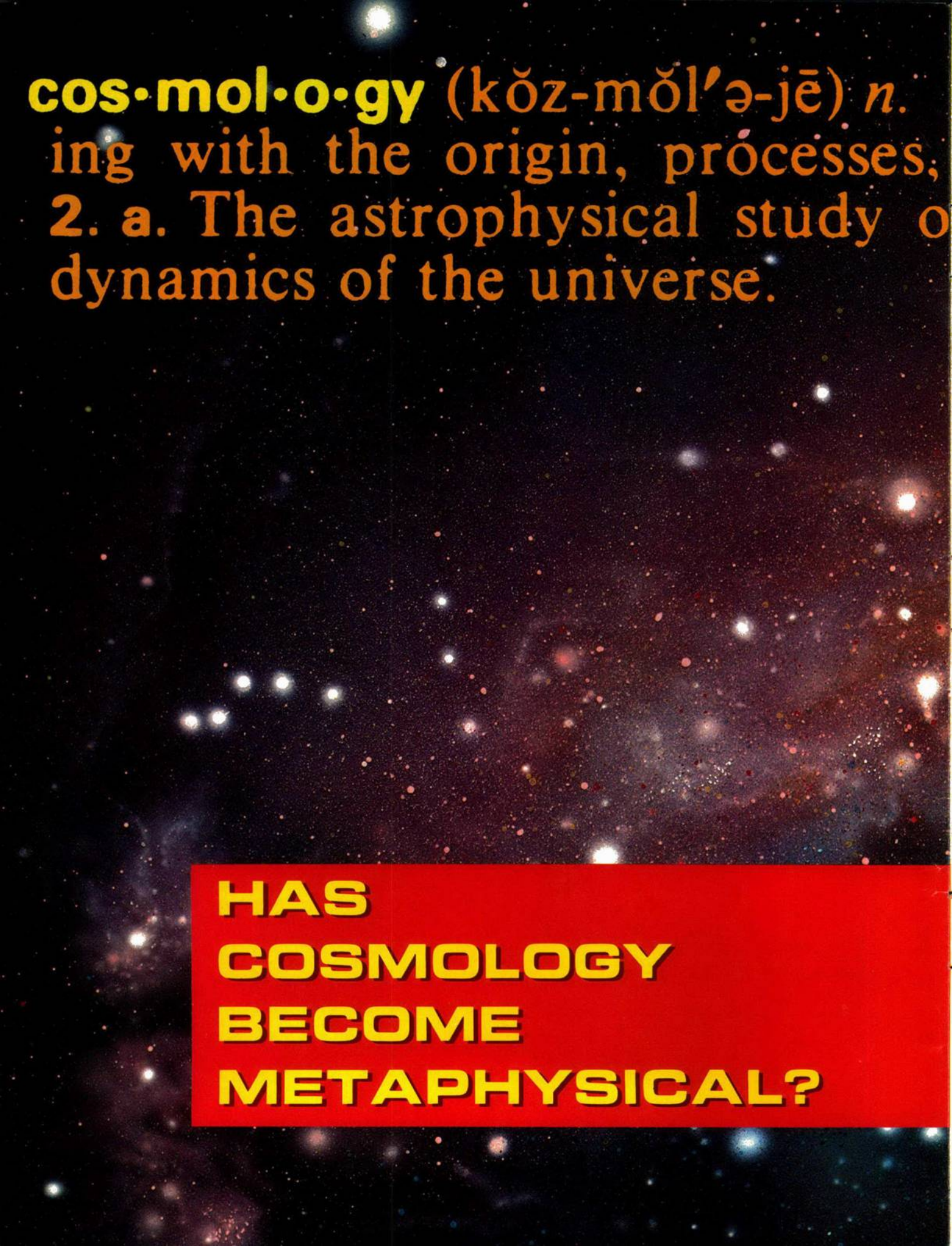
Sculpting the Moon
by Michael T. Kitt

Vela/Pyxis

Cover: During their three days on the Moon in 1971, the Apollo 15 astronauts explored several geological features in the Lunar Rover: the heavily cratered highlands near the Apennine Mountains, the dark volcanic lavas of Mare Imbrium, and the meandering channel named Hadley Rille, which is etched into the mare floor. From the Apollo missions, selenographers (Moon scientists) have been able to retrace some of the events and processes that sculpted the surface of the Moon over the last 4 billion years. These pages: The Moon photographed from Earth orbit by the crew of the post-Apollo Skylab 3 mission in 1973. NASA photos.

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cos·mol·o·gy (kŏz-mŏl'ə-jē) *n.*
ing with the origin, processes,
2. a. The astrophysical study of
dynamics of the universe.

**HAS
COSMOLOGY
BECOME
METAPHYSICAL?**

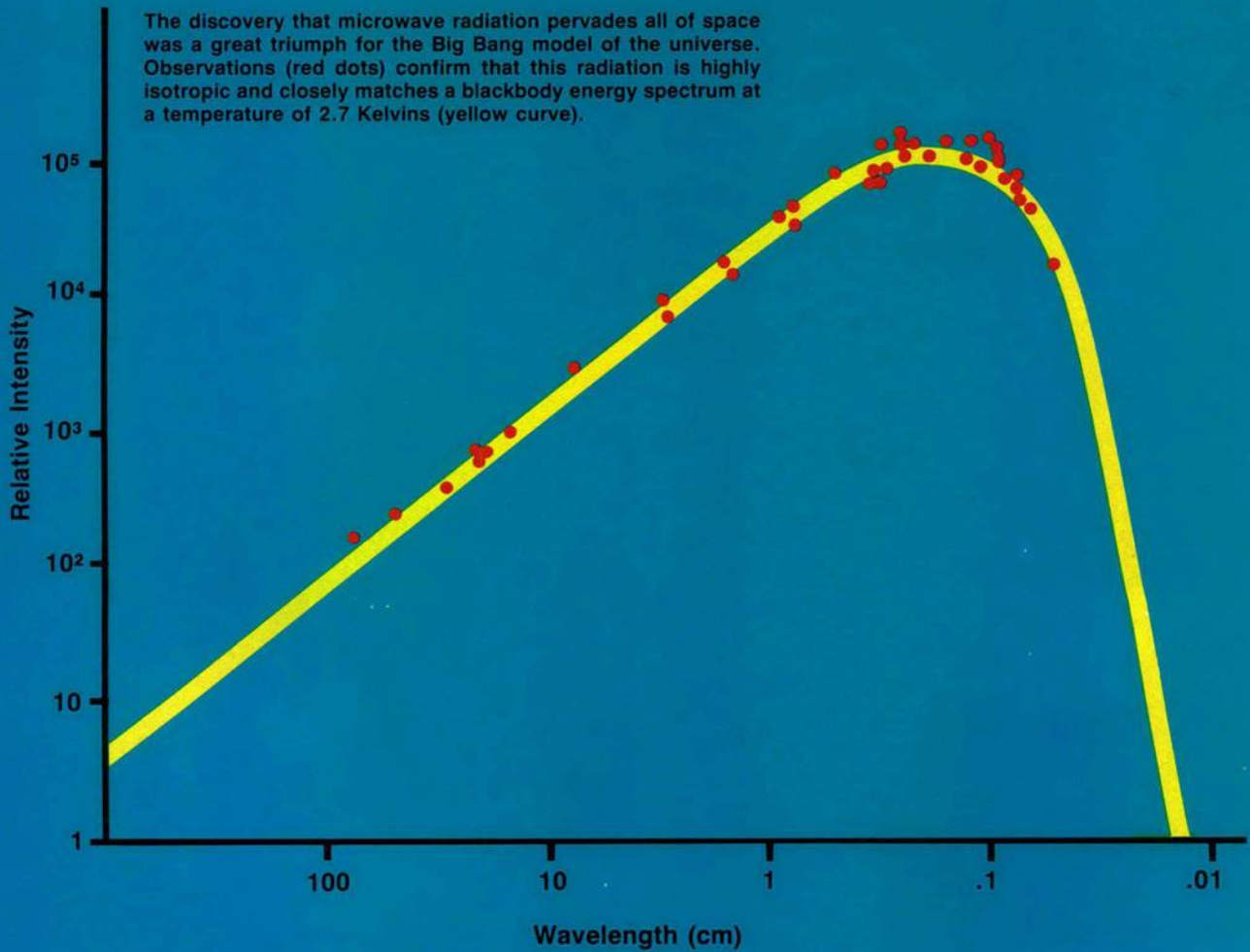
1. A branch of philosophy deal- and structure of the universe. f the structure and constituent

Over the centuries man's study of the origins of the universe has progressed from philosophical speculation to scientific inquiry. Recent developments in cosmology, however, indicate that the pendulum is swinging back to a reliance on metaphysical assumptions.

by Tony Rothman and George Ellis

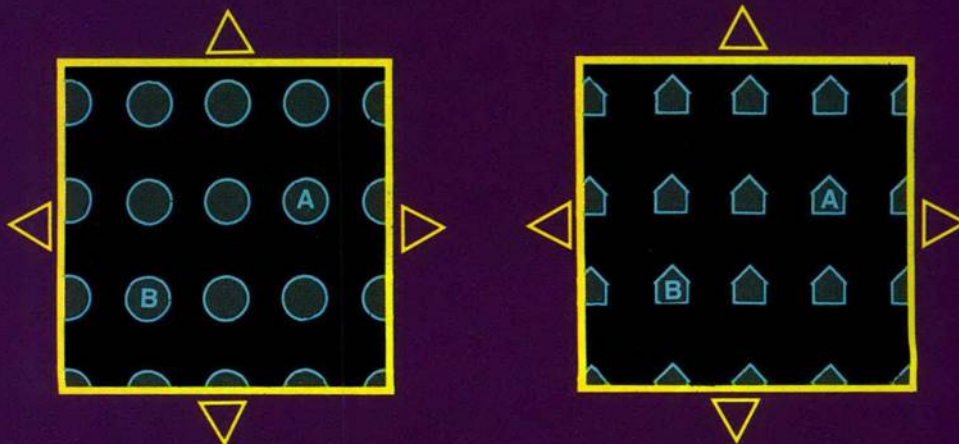
The Cosmic Background

The discovery that microwave radiation pervades all of space was a great triumph for the Big Bang model of the universe. Observations (red dots) confirm that this radiation is highly isotropic and closely matches a blackbody energy spectrum at a temperature of 2.7 Kelvins (yellow curve).



Homogeneous or Isotropic?

Our universe is usually considered both homogeneous and isotropic, like the one shown at left. The universe has the same properties at points A and B, and it looks the same in every direction. At right is a homogeneous but anisotropic universe: it still looks the same at points A and B, so it is homogeneous; but because it does not look the same in all directions — you see arrowheads looking "south" and arrow tails looking "north" — this universe is not isotropic.



Physics and metaphysics. Nature and beyond nature. The distinctions seem to be fairly clear. Physics is a science: it deals with questions that can be decided by observation and experiment. Metaphysics deals with issues that do not admit defeat so easily: the existence of God, the content of the soul.

In the twentieth century scientists pride themselves on maintaining the distinction between the two. Cosmologists attempt to answer the question of *how* the Big Bang occurred; they do not speculate on *why* the Big Bang occurred.

We do not want to give the impression that the difference between physics and metaphysics suggests science versus religion. In fact, the word "physics" derives from the Greek *physika*, which literally means "things of nature." "Metaphysics" comes from *meta ta physika*, literally "after the things of nature." The term was first used by Aristotle's Hellenistic editors to refer to the texts that followed his books on physics. Medieval theologians were convinced that these texts came "after the things of nature" because they dealt with subjects further removed from direct perception. Since then metaphysics has always connoted something that transcends physics and, after Immanuel Kant, metaphysics took on its common meaning: the study of questions that cannot be proved or disproved by scientific experiments.

A few centuries ago scientists often speculated on metaphysical matters. Isaac Newton had no difficulty postulating that the force of gravity obeys an inverse-square law and, at the same time, declaring that God was necessary to prevent the universe from collapsing under the same law of gravity. The first assertion is a testable hypothesis, the second is not. Many scientists of the seventeenth and eighteenth centuries, including the great Dutch physicist and astronomer Christiaan Huygens, believed the cosmos was filled with inhabited worlds simply because such a universe was more worthy of the infinite Creator than a universe occupied by one lonely Earth.

Nevertheless, Newton's mechanics and its descendants proved so successful at eliminating God and similar untestable hypotheses from scientific explanation that,

three hundred years later, science has a different voice altogether. Steven Weinberg said in his book *The First Three Minutes*: "The more the universe seems comprehensible, the more it also seems pointless."

The quest for a theory capable of describing all the major features of the universe has become a sort of "holy grail" to cosmologists. One of the newest of these theories — inflation — has been an important step in this direction. As an extension of the Big Bang theory it both retains the successes and apparently avoids the failures of the Big Bang theory. But inflation also raises some important questions about the direction of cosmological inquiry in the 1980s: Is the twentieth-century distinction between physics and metaphysics still valid? Has cosmology returned to the philosophical stage by making untestable predictions? Are the assumptions on which cosmology rests verifiable? Should present-day cosmology be called cosmology or "metacosmology?"

The Big Bang Universe

Astronomers and astrophysicists have labored long and hard to develop a comprehensive and reasonable model of the universe. The currently favored model is the Big Bang, an outgrowth of the discovery earlier this century that the universe is expanding, possibly from an original extremely dense state. The standard Big Bang model assumes that the matter and radiation content of the universe started to expand at some finite time in the past, thought to be between 10 and 20 billion years ago, and continues to do so.

The Big Bang model assumes the universe is *homogeneous* and *isotropic*. A homogeneous and isotropic universe contains no irregularities that would allow you to distinguish one location from another: matter is distributed in an absolutely uniform fashion. For this reason a universe simpler than the standard Big Bang model is difficult to imagine.

Homogeneous means that, on a large scale, the universe appears the same from every vantage point. If we were to travel to any point in the universe, the universe would appear the same as it does in our neighborhood. An isotropic universe, on the other hand, appears the same to us in every direction. You might imagine yourself an



The Big Bang theory has a lot going for it, but the standard model is far from perfect. The best theory we have now is inflation: it solves the major problems arising from the Big Bang scenario and then goes much further. It may, in fact, be our final cosmological theory.

The problems that inflation tries to solve are metaphysical in nature! And, there is no evidence to support inflation, while its one testable prediction contradicts observational data.



ant in the middle of a desert with nothing but identical grains of sand surrounding you. This would be a very isotropic world. It turns out that a universe that is isotropic everywhere is also homogeneous, though a homogeneous universe is not necessarily isotropic.

It is important to note that the real universe is observed to be highly isotropic when we look at it on a large enough scale, but we cannot verify that the universe is homogeneous because we cannot travel far from Earth — by cosmological standards — to make the necessary observations.

In the standard Big Bang model the density of matter determines the ultimate destiny of the universe. If the density exceeds the so-called "critical density" of about 2×10^{-29} grams per cubic centimeter, gravitational attraction will eventually halt the expansion of the universe and this will be followed by a universal contraction. In this case the model is usually called "closed." If the matter density is less than the critical value, the universe will continue expanding forever. Such a model is referred to as "open." If the matter density is exactly critical, the universe is said to be "marginally bound" or "flat," which means it is destined to expand forever, but at an ever-decreasing rate that approaches zero.

Two of the reasons the Big Bang model has gained such a following are its successful predictions of the observed abundances of helium and deuterium in the universe and of the existence of the cosmic background radiation. The formation of helium and deuterium started just three minutes after the Big Bang when temperatures were about 1,000,000,000 Kelvins. At this stage neutrons combined with protons to form deuterium nuclei, and these in turn combined to form helium nuclei, a process

that took just a few minutes to complete. The resulting abundances of these two nuclei depend on the matter density of the early universe, and observations generally agree with the theoretical predictions.

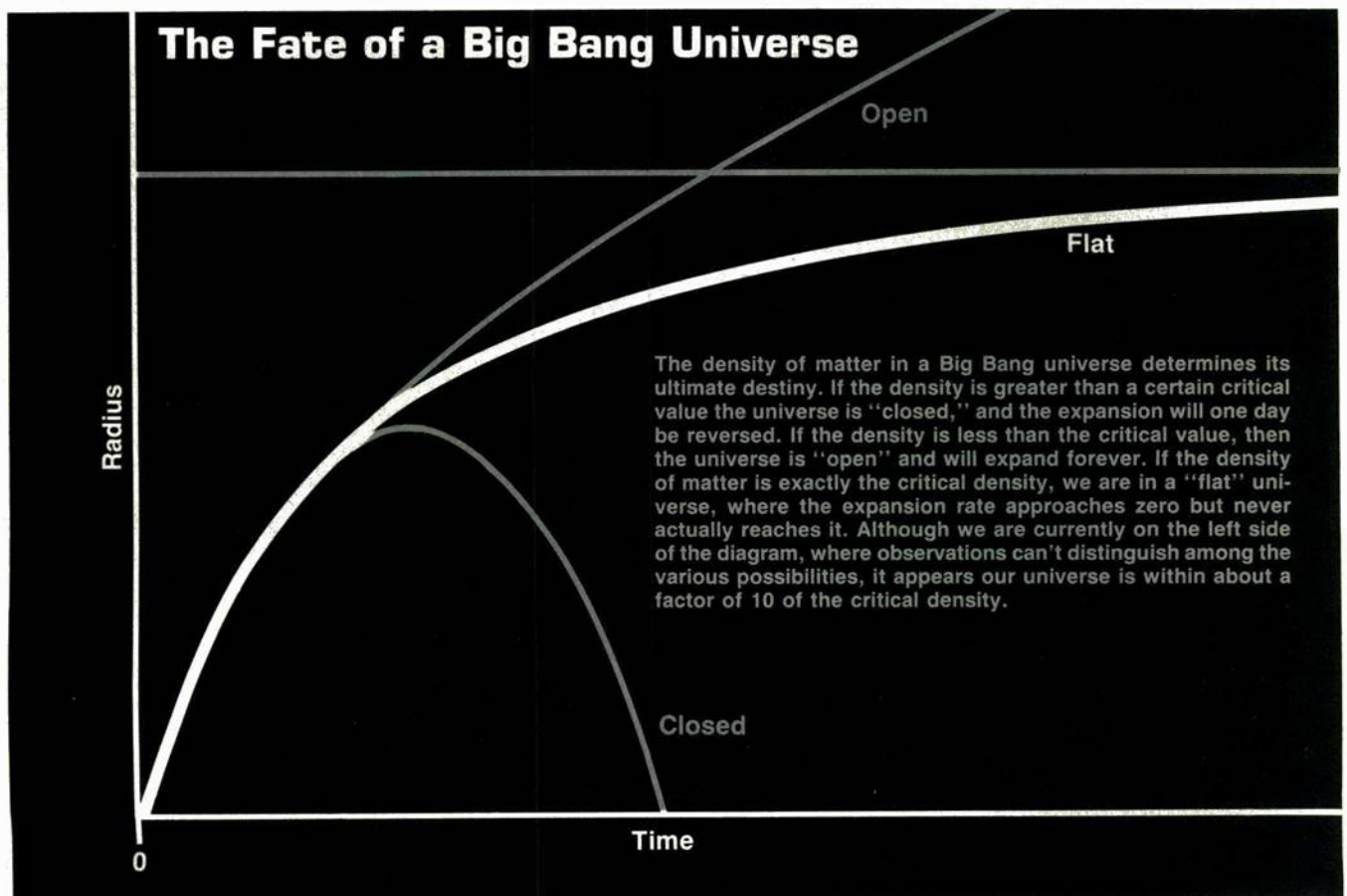
In the late 1940s, Ralph Alpher and Robert Herman first predicted that microwave radiation pervades all of space. They were investigating the synthesis of elements in a Big Bang universe when they realized that the radiation content of such an explosion would still be visible today as a cosmic background. This prediction was confirmed in 1965 by Bell Laboratory researchers Arno Penzias and Robert Wilson, who discovered this faint echo while searching for sources of radio interference.

The standard model is not without its problems, however. The most serious difficulty of a physical nature is the existence of a singularity at the instant of the Big Bang. At this moment the density, pressure, and temperature were all infinite, and the known laws of physics did not yet apply. Spacetime, and indeed physics itself, came into existence at this time.

A serious philosophical difficulty with the Big Bang model is its assumption that the universe started off exactly isotropic and thus exactly uniform everywhere. Of all the possible starting points, the standard model requires this exceptional one.

Problems with the Standard Model

The standard model also turns out to have some other problems that are not so well known. These conundrums are what Massachusetts Institute of Technology physicist Alan Guth set out to solve with his "inflationary universe" scenario in 1981. In this theory he postulated that the universe underwent a brief but extraordinary period of expansion early in its history.



The Scale of the Universe

Radius

The radius of the universe has a markedly different history in the standard Big Bang model (yellow) than it does in the inflationary scenario (red). Shortly after the Big Bang the radius of the inflationary universe was many orders of magnitude smaller, but at 10^{-35} seconds it underwent a period of exponential expansion. After the inflationary epoch the two radii are identical.

Time



How can you explain the observational data that shows the universe is nearly at the critical density? The inflationary scenario gives us sound reasons to believe the universe should be at the critical density, and we're confident this prediction will be borne out.

The easiest way to explain this is the way the Big Bang theory does: the universe was exactly flat at the moment of the Big Bang. Now I'm not saying this explanation proves anything — even I feel we need a better one — but it does imply that the problem is metaphysical.



The first puzzle Guth addressed is known as the “flatness problem,” which has been emphasized during the last decade by Robert Dicke and Jim Peebles of Princeton University. The flatness problem is based on astronomical measurements that show the density of matter in the observed universe is within roughly a factor of 10 of the critical density. Most, if not all, observational and theoretical studies indicate that the density of baryons in the universe (baryons are the class of subatomic particles that interact through the strong nuclear force and include the proton and neutron) lies between about 4 and 10 percent of the critical value. In principle, the density of matter could have any value and, from a statistical viewpoint, the chances that the value is so close to the critical value are remote.

It could be just a coincidence that the universe is nearly flat, but physicists feel uncomfortable with coincidences and search for underlying causes. However, if the universe is currently within a factor of 10 of being flat, an even more troublesome problem presents itself: the universe must have been flat to approximately one part in 10^{15} at one second after the Big Bang, and at 10^{-35} seconds — the Grand Unified epoch when the electromagnetic force and the strong and weak nuclear forces were all combined into one — the universe must have been flat to one part in 10^{50} . Many physicists feel that such “fine tuning” needs an explanation. Others point out that in the standard model the universe is exactly flat at the instant of the Big Bang, so it shouldn’t be surprising that the universe was tuned to one part in 10^{50} at 10^{-35} seconds.

In essence, the flatness problem can be dismissed simply by making different assumptions about the initial

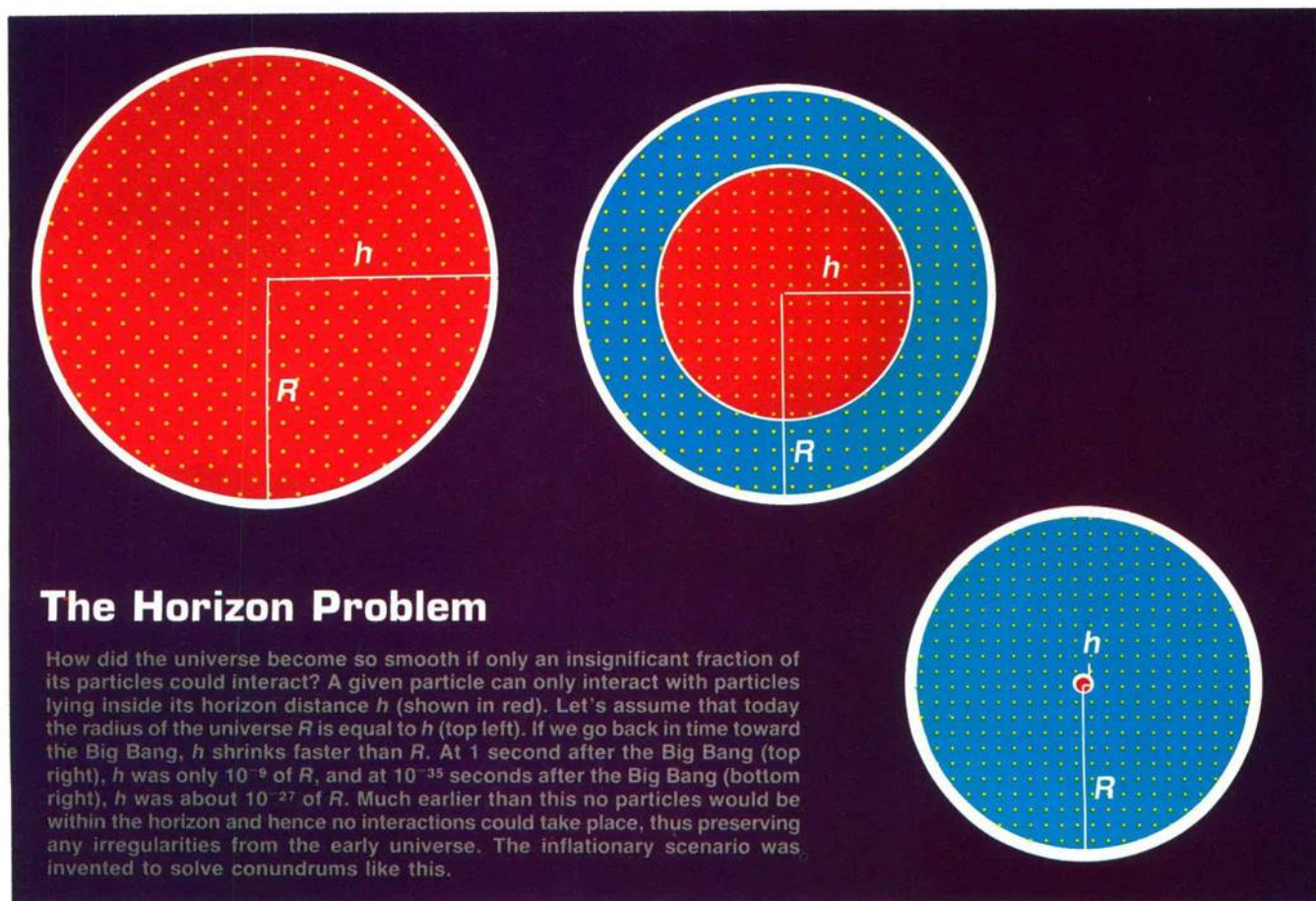
conditions of the universe. Consequently, the problem is metaphysical, not physical.

A second conundrum, known as the “horizon problem,” was pointed out by Wolfgang Rindler in 1956. To understand the horizon problem we must examine a feature of the standard model not discussed in most popular accounts: that there are actually two sizes to the universe. The first size is simply the age of the universe (t) multiplied by the speed of light (c), or $h = c \times t$. Because no signal can travel faster than the speed of light, no information can be received from a distance farther than h , which is called the horizon distance. In other words, you can have no knowledge of events taking place beyond your horizon, which forms the edge of your observable universe.

The second important measure of distance in the standard model is the cosmic scale factor R . In a closed model, R is simply the radius of the universe. This is not strictly true in an open model (since the size of the universe is infinite), so we will limit our attention to closed models for simplicity.

The number of photons inside the universe does not change as the universe expands or contracts. If the radius decreases by a factor of 2, the average separation between photons also decreases by a factor of 2, so all the photons would be contained in a volume smaller by a factor of 8 (since volume is proportional to R^3).

As the universe expands, however, h increases faster than R . Conversely, as we go back in time, h decreases faster than R . Estimates place the number of photons in our universe at about 10^{87} . Let’s assume that all 10^{87} photons are observable today, so the horizon size must equal the cosmic scale factor ($h = R$). If we imagine



A straightforward calculation shows that at one second after the Big Bang h was only about $10^{-9}R$ and only 10^{60} photons could be observed, which is an insignificant fraction of 10^{87} . At 10^{-35} seconds, h was about $10^{-27}R$ and roughly one million photons were within the horizon. At 10^{-43} seconds, essentially no photons were within the horizon.

Many cosmologists feel it is highly improbable that the universe began in an absolutely isotropic fashion. To them it seems far more likely that the Big Bang occurred in a chaotic fashion and gradually became isotropic. Cosmologists inclined toward this point of view might be termed advocates of the Principle of Greatest Probability. Unfortunately, the horizon problem puts members of the Greatest Probability Sect into a serious blind alley, because the universe had no way of becoming isotropic. Since particles farther apart than the horizon distance could not interact after the Big Bang, in principle they had no method by which they could have smoothed out any irregularities on scales larger than this distance. And yet the universe is observed to be highly isotropic. The question posed by the horizon problem can be rephrased: Why is our present universe not chaotic?

If you are inclined toward this point of view, there is no need to explain the isotropy of the universe — you have assumed it from the beginning. The horizon problem becomes irrelevant. Particles near the time of the Big Bang were unable to interact with one another and through this process isotropize the universe, but any such contact would have been superfluous because the universe was already expanding isotropically.

The Next Step: Inflation

February 1987

Imagine yourself an ant crawling on the surface of a balloon. In its uninflated state the balloon may be small enough for the curvature of the surface to be visible and for you to circumnavigate the globe in a short time. Now suppose the balloon is suddenly inflated by 30 or 40 orders of magnitude, that is, by a factor of 10^{30} , 10^{40} , or even more. As a lowly ant, you will see a surface that is flatter than the Great Plains, and the horizon, which had been very close, will now be so far away that you cannot see it.

The Time Frame of Inflation

1 sec

15 billion years

10⁻¹⁷ sec

1 sec

 10^{-35} sec 10^{-17} sec

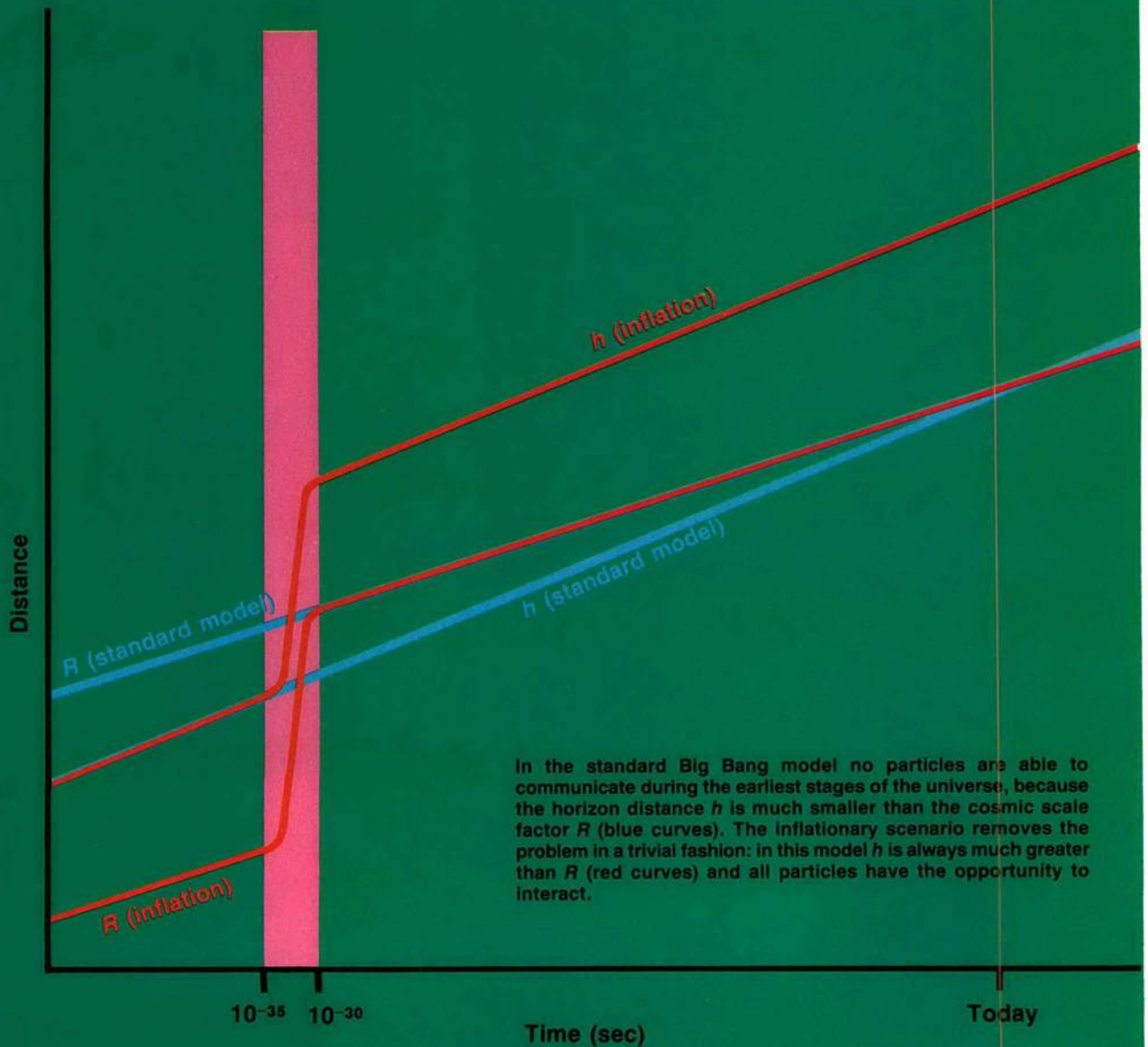


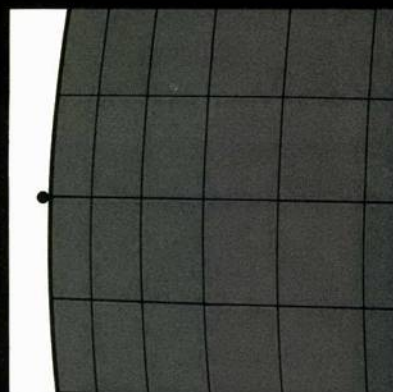
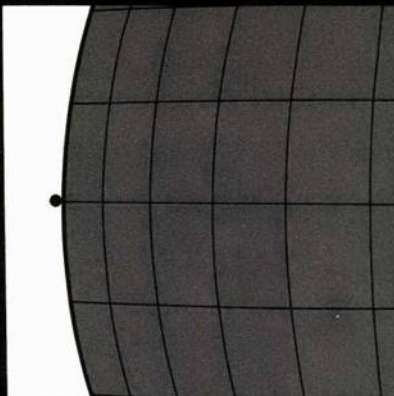
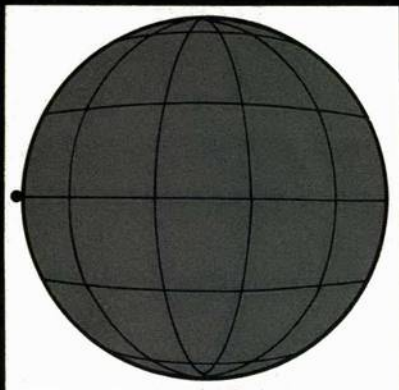
The standard model doesn't explain why the universe appears isotropic, unless it started out that way. The inflationary epoch takes any initial conditions and leaves us with the universe we see today.



But you can also make the horizon problem disappear by assuming that the Big Bang was initially isotropic. So the horizon problem should be considered a metaphysical problem — not a physical one.

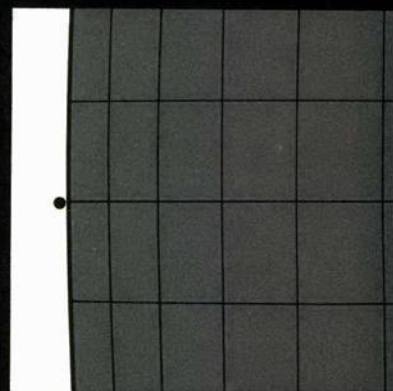
Defeating the Horizon Problem





Solving the Flatness Problem

The inflationary hypothesis suggests that the universe underwent a brief period of expansion, increasing in size by a factor of 10^{30} , 10^{40} , or greater early in its history. In this schematic we see the geometric effects of this scenario on an ant crawling on the surface of a balloon. Moving clockwise from the top left, each sketch in succession shows the balloon inflated by a factor of 3. The curvature of the surface quickly becomes undetectable to the ant and his world becomes flat, despite a total inflation factor of only 27 times. Inflation has a similar effect on the universe: the geometry becomes flat and the density is driven to the critical value.



magnitude. Such inflation would make the universe phenomenally flat.

Since a flat universe is at the critical density, the universe is driven toward the critical density during the inflationary period. In other words, regardless of the density before inflation, after inflation the density must be, to a high approximation, critical. The universe is, for all intents and purposes, flat, and the flatness problem disappears. The most important prediction of the inflationary scenario is that the density of the universe should now be critical.

The horizon problem vanishes with the same stroke, which is not surprising if the two puzzles are not distinct. In the standard model, at 10^{-35} seconds the horizon size is approximately 10^{27} times smaller than the scale factor, so particles would have been unable to interact. If the horizon were 10^{27} times larger or, conversely, the scale factor were 10^{27} times smaller than previously thought, the horizon problem would disappear. Inflation allows this possibility. At early times the scale factor was, contrary to the standard model, *smaller* than the horizon size, so all the particles in the universe could communicate and smooth out any irregularities.

We should emphasize that inflation provides a necessary, though not sufficient condition for isotropy. Particles had the opportunity to interact, but inflation does not specify how they interacted. Either some other mechanism needs to be invoked to explain how the universe became isotropic or the inflationary scenario itself should show that, regardless of the initial state of the universe, the final result is always homogeneous and isotropic.

Inflationary Physics

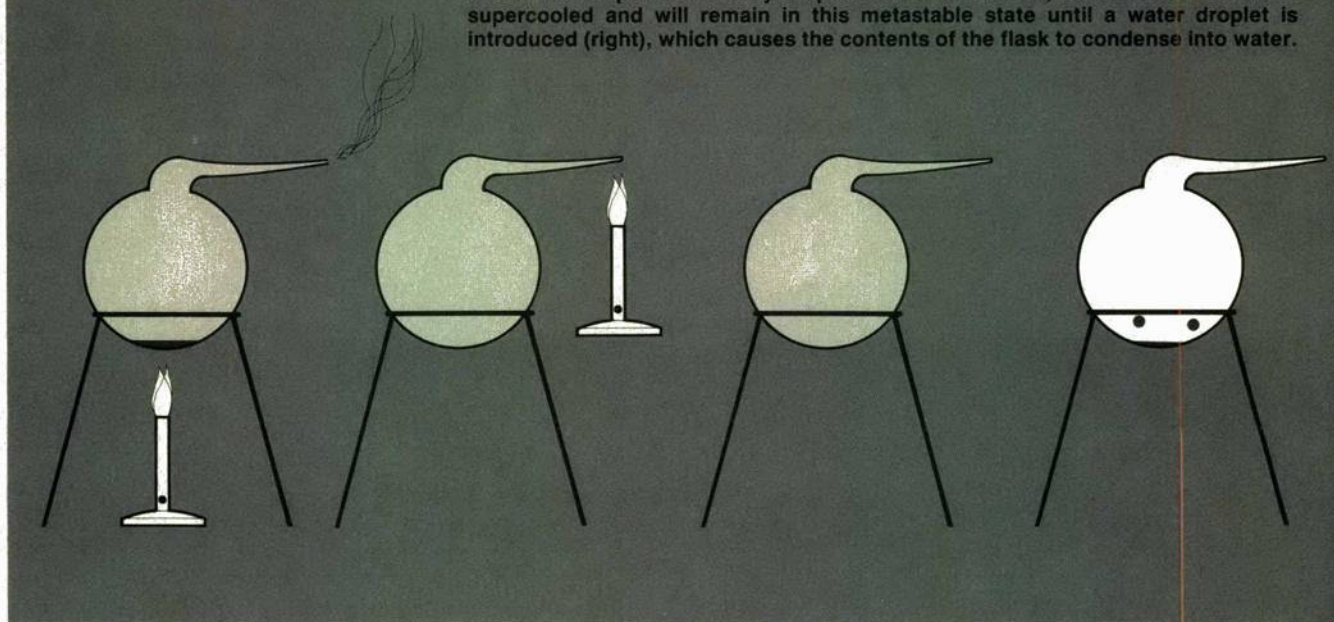
To describe what inflation does is one thing, to explain why it takes place is quite another. In his original inflationary scenario Guth proposed that the universe experienced a phase transition similar to what occurs when a substance changes between its solid, liquid, and gaseous phases. Once again we will resort to an analogy. If you take a flask of steam at a very high temperature and cool it gradually, its temperature can fall below the condensation point of 100° Celsius without condensation taking place. Steam that exists below 100° is referred to as supercooled. The state is highly unstable; if the smallest water droplet is introduced into the flask, the steam will quickly condense around the droplet until the contents of the flask have turned into liquid water.

Guth postulated that as the universe expanded and its contents — photons, electrons, baryons, neutrinos, and other particles — cooled, the energy associated with the vacuum of spacetime cooled as well. (In modern physics the vacuum of spacetime is far from empty. It is an arena where particles can be created and destroyed and which possesses many properties that can be calculated and measured. This "ground state" of the universe is associated with an energy density that also changes as the universe expands.) At about 10^{-35} seconds, as the ordinary particles continued to cool, the vacuum energy got "hung up" in a supercooled state.

According to the theory of general relativity, the expansion rate of the universe depends on the energy density of its contents. In the standard model, the energy density of the particles decreases as the universe expands,

Inflation Physics

In this analogy of the physics of inflation, a flask of water is heated with a Bunsen burner (left). When all the water evaporates the flask is sealed and only steam is left. If the temperature slowly drops below 100° Celsius, the steam can become supercooled and will remain in this metastable state until a water droplet is introduced (right), which causes the contents of the flask to condense into water.



which causes the expansion rate to drop. But the inflationary universe suggests that the vacuum energy got hung up at a higher, constant value that allowed the expansion to proceed at a higher, constant rate than it would have in the standard Big Bang. This period of excess expansion is the inflationary epoch. If the vacuum energy remained constant for a long enough time, the universe could have expanded the required factor of 10^{30} or 10^{40} . At some point condensation sets in: a "water droplet" is introduced into the supercooled system, the vacuum energy quickly decays to the value it would have had under ordinary circumstances, and inflation ends.

Guth did not perform elaborate calculations to prove such a supercooled state of the universe *would* take place. He suggested it was *plausible* and, if it did occur, inflation would result.

There is a severe problem with the original inflationary scenario, however. Guth realized that the decay of the vacuum energy, like the condensation of steam, would occur at different times in different places. But, because the universe is expanding, the decay rate of the vacuum must catch up with the expansion of the universe for the condensation to be completed everywhere. Guth determined that this would not generally happen and therefore the resulting universe would be highly irregular, with some parts in one state and some parts in another. Because we observe the universe to be highly regular, this difficulty ruled out "old original" inflation.

The introduction of "new" inflation by Linde and Albrecht and Steinhardt solved this problem. The mechanism behind new inflation is conceptually more difficult, so we will not delve into the details. It is enough to say that the vacuum energy exists in this scenario as well and remains at a sufficiently high value for a sufficiently long time to drive inflation. The essential difference between the two versions is that in new inflation one small bubble of space is inflated to encompass the entire known universe — and more. We do not see any

irregularities because they have all been pushed far beyond our horizon.

New inflation has an additional advantage over old inflation in that it solves a third cosmological conundrum: the "monopole problem." (A magnetic monopole can be thought of as a single north or south pole of a magnet.) The Grand Unified Theories (GUTs) that attempt to combine the strong nuclear, weak nuclear, and electromagnetic forces into one comprehensive theory predict that the universe should be filled with monopoles, and yet none has ever been observed.

New inflation solves this problem in a trivial fashion, saying the high density of monopoles in the early universe is simply diluted by the period of inflation. The volume of space increases to such an extent that you would expect, on average, one monopole in the observable universe — and we have not yet found the one in ours.

Unfortunately, while new inflation has had its successes, a number of diseases have also been diagnosed — we now mention two. First, the universe apparently decays into the wrong vacuum. Loosely speaking, inflation puts us into a universe where the physics of the "ground state" is not the physics predicted by the currently favored theory. This vacuum eventually decays into ours, but the decay occurs unevenly, as it does in old inflation, leaving a highly irregular universe. New inflation effectively leaves us with the original problem.

Second, new inflation predicts that fluctuations in the density of matter exist after the inflationary period comes to an end, and it further predicts the size of these fluctuations. Galaxies are obviously fluctuations in the density of matter in the universe: the matter density is higher inside galaxies than outside. Some theorists assert that fluctuations of a certain size are needed at 10^{-30} seconds after the Big Bang to initiate galaxy formation. Inflation, however, produces fluctuations about 100,000 times too large for galaxies as well as 100,000 times larger than the measured uniformity of the cosmic microwave back-



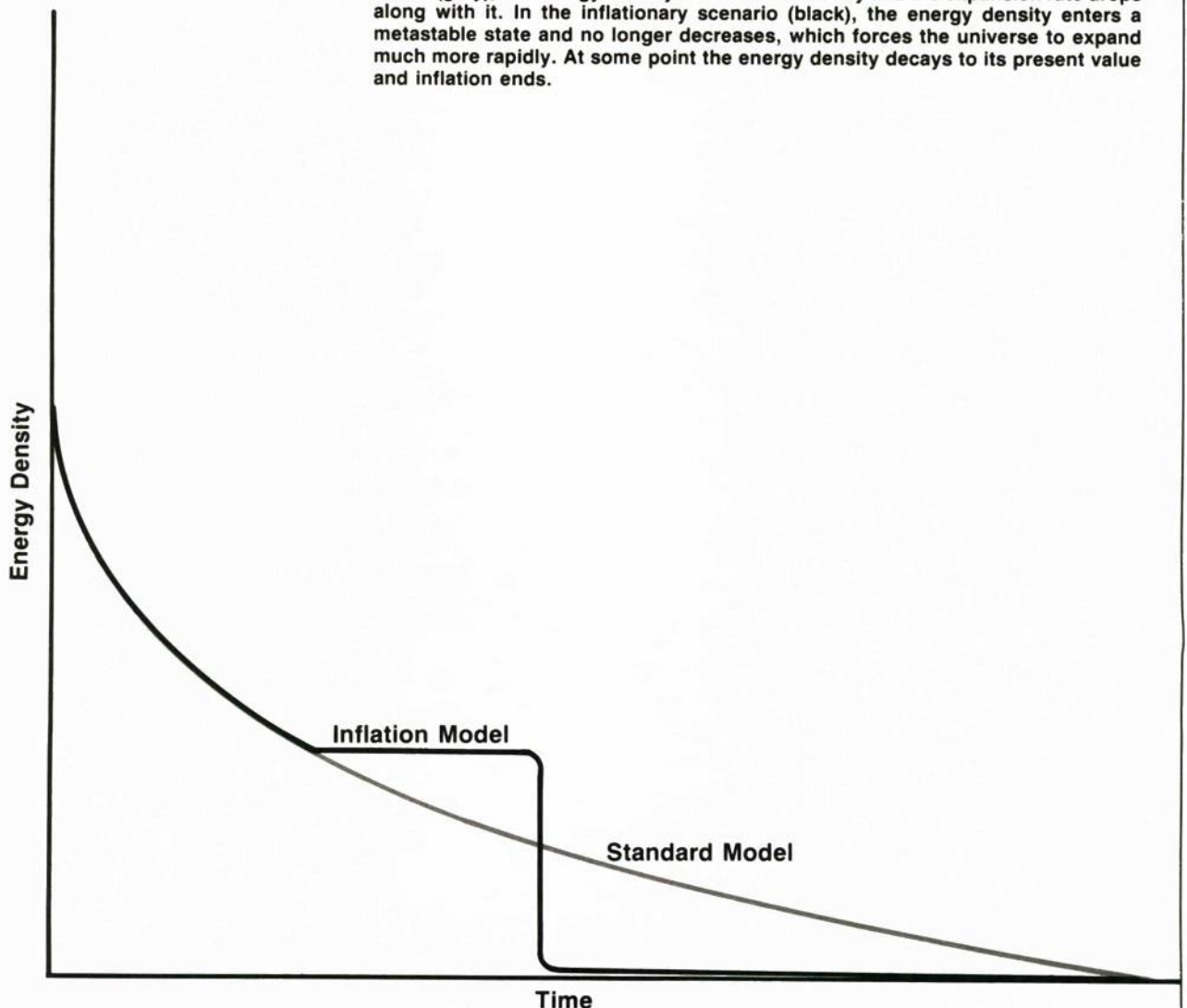
Inflation took place as the universe was cooling and its vacuum energy density got hung up in a supercooled state. Though this state only lasted a brief time, it is responsible for the regularity in our universe.



But in both the old and new versions of inflation the vacuum energy density decays irregularly, so you have not shown why our universe appears regular.

How the Universe Expanded

The energy density of the universe determines its expansion rate. In the standard model (gray), the energy density decreases smoothly and the expansion rate drops along with it. In the inflationary scenario (black), the energy density enters a metastable state and no longer decreases, which forces the universe to expand much more rapidly. At some point the energy density decays to its present value and inflation ends.





Why do we have a universe that appears homogeneous and isotropic? Of all the possible universes, this special one is what we have — and inflation explains why this is so.

There is only one universe at our disposal, and you can't conduct a statistical study with one data point. Who's to say what an "average" universe is like?



One powerful aspect of the inflationary theory is that it will convert any kind of initial universe into the one we live in now.

No one questions that inflation is a powerful theory, but if it's correct, then any other theory that attempts to make statements about the pre-inflationary period must be metaphysical.



Our calculations show that the inflationary scenario is entirely plausible, and it will take place if the vacuum energy density gets trapped in a supercooled state.

Yes, but most of the calculations have been done in isotropic models. Inflation meets its real test in the anisotropic and inhomogeneous models, and preliminary results show that inflation may not occur in all of these models.



You were quick to point out that new inflation predicts large fluctuations in the early universe, and this contradicts one theory of galaxy formation. None of these theories is close to being verified, so ruling out inflation on this point is meaningless.

Although some of the arguments against inflation seem to be untestable, more definitive tests have also cast serious doubt on inflation.



Inflation is based on the Grand Unified Theories of physics, which are proving to be successful in describing nature. The validity of these theories strengthens our confidence in inflation.

But these theories are far from being proved. In fact, they predict that the proton decays and, though the measurements are not easy to make, no experiment has yet found evidence for this decay. If the GUTs have to be thrown out, inflation will go at the same time.



ground radiation will allow. For these reasons, most cosmologists have rejected new inflation and are searching for newer and improved versions.

"Metaflation"

The inflationary theory set out to solve two problems, — horizon and flatness — and on the way happened to solve a third, the monopole puzzle. But in reality inflation attempts to do much more.

Guth's original scenario showed that, regardless of the initial density of the universe, the current density should be critical. Any model or theory that shows that the final state of the system is independent of the initial conditions is very powerful. If you could prove that inflation would take any universe — highly chaotic, anisotropic, inhomogeneous — and produce the isotropic universe we observe today, then the scenario would have accomplished a great deal. Because this is the hidden agenda of inflation, many theoreticians are highly prejudiced in its favor. Indeed, some popular accounts have already implied that inflation is a verified theory.

We now ask the awkward questions: Is this prejudice justified? Has inflation in any way been verified? We want to warn our readers that the following opinions challenge accepted beliefs and will undoubtedly incur the wrath of our colleagues.

First, we reiterate that the problems inflation set out to solve have a different character than predictions of the perihelion shift of Mercury or the spectral lines of helium — problems where we can experimentally measure the correct results. Rather, the flatness and horizon problems strike us as suspicious. Unfortunately, there is only one universe at our disposal. No one can claim to know with certainty how universes behave in general and therefore whether the average universe should be flat or curved, isotropic or anisotropic. Cosmologists are free to assume the cosmos began flat and isotropic, in which case the questions that inflation addresses disappear. Consequently, these issues are philosophical and not physical in nature.

Second, assume that the grand design of inflation is correct, that any set of conditions before inflation will yield the universe we live in. This means, conversely, that by observing the present universe we cannot "retrodict," or predict backward in time, and describe what the universe was like before the inflationary period. Any result would be valid since any initial universe would have given rise

to the present universe.

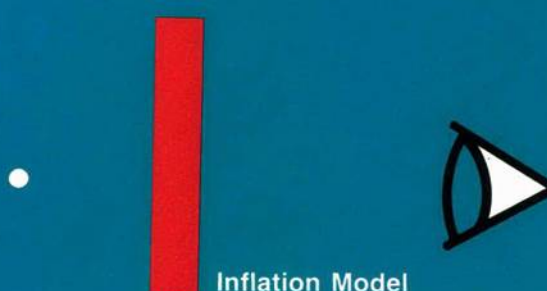
For example, the theory of quantum gravity, which attempts to make statements about the pre-inflationary epoch, must make untestable predictions. This example is not, of course, an argument against inflation. It does mean, however, that either inflation is incorrect or that some other branch of cosmology must become meta-physical.

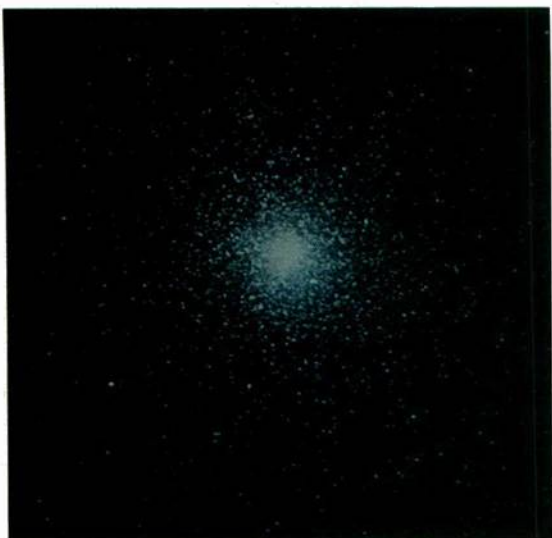
To ask whether inflation really fulfills the grand design is an appropriate question. Although some theorists claim that inflation takes place in anisotropic and inhomogeneous cosmologies, most detailed calculations up to now have been carried out in isotropic models. We have already shown that the horizon problem cannot be solved in an isotropic universe because there is no problem, so it is unclear whether these calculations have logically solved anything. Researchers have only recently begun to investigate inflation in both anisotropic and inhomogeneous cosmologies, and while evidence is accumulating to show that inflation can indeed take place in most anisotropic models, inflation may very well not occur in a large class of inhomogeneous models.

However, we should also point out that some of the arguments used against inflation also appear to be untestable. New inflation was discarded partly because it predicted fluctuations at 10^{-30} seconds, which conflicted with a certain model of galaxy formation. There is so much disagreement over the nature of galaxy formation, not to mention the state of the universe at 10^{-30} seconds, that no argument on this point can be taken as resting on ironclad physical principles. As a result, one unverified model has been thrown out because of another unverified model. On the other hand, a much more concrete reason for rejecting new inflation would be that it conflicts with observations of the microwave background — if you believe that the predicted fluctuations could not have been damped out within 100,000 years after the Big Bang, when the microwave background was created.

Is there any experimental evidence to support inflation? One can only say no. The correctness of inflation fundamentally depends on the correctness of the Grand Unified Theories that provide its foundation. The standard GUT model makes the startling prediction that the proton decays into lighter particles in roughly 10^{32} years, and yet elaborate experiments built to measure this phenomenon

As we probe closer to the Big Bang, we eventually reach a wall we can't see beyond. In the standard model this wall doesn't come until we reach the instant of the Big Bang — to ask what came before that is a metaphysical question. Because the inflationary epoch turns any initial conditions into the universe we see today, the wall beyond which we can't see occurs at 10^{-35} seconds.





The age of globular clusters puts constraints on the inflationary theory. The theory predicts that the universe formed no more than about 14 billion years ago, yet recent observations of the cluster NGC-6752 show that its stars are between 14 and 18 billion years old.

have yet to detect it. If GUTs are eventually thrown out, inflation will be thrown out as well.

On the Trail of the Missing Mass

The one testable hypothesis inflation makes is that the universe should be at the critical density exactly, and this prediction appears to be incorrect. We mentioned earlier that almost every study indicates that the current density of the universe is substantially less than the critical density. To be more specific, the observed helium abundance can only be produced if the density of baryonic matter is not much more than 5 percent of the critical value. Studies of the motions of galaxies and of clusters of galaxies might push this number up to 10 percent or so.

There are only two alternatives for dealing with this dilemma: either discard inflation because it is contradicted by observation or postulate some unobserved form of matter to account for the other 90 percent of the universe's mass. Theoretical cosmologists have chosen the latter alternative. The most obvious candidate for this "missing mass" is the massive neutrino, which was reportedly discovered in 1980. Although these neutrinos would not be very massive, they are plentiful: neutrinos outnumber protons and neutrons by about one billion to one. If these neutrinos have a mass equal to just 1/50,000 the mass of an electron, their total mass density would be sufficient to close the gap between the observed density and the critical density. However, the 1980 results that implied a mass for the neutrino have not been duplicated, and we are forced to conclude that there is as yet little, if any, evidence for such particles.

Theoreticians have not been deterred, however. Grand Unified Theories and their newer counterparts, Susy GUTs, predict that many so-far-undetected particles would have existed at 10^{-35} seconds after the Big Bang. Such entities could have decayed into lighter particles, similar to massive neutrinos, that would inhabit the universe and provide the missing density. We want to emphasize that there is no evidence these particles exist. You can take the theoretician's point of view that GUT and Susy-GUT particles will soon be discovered and that the entire GUT-inflationary complex will be vindicated, but this position may lead to severe contradictions to astronomical observations of the age of the universe.

The Big Bang theory predicts the universe began at some finite time in the past. The exact age of the universe depends on the expansion rate, which in turn depends

on the density of matter and whether the contents of the universe consist primarily of baryons or radiation (particles that behave essentially like photons and travel at lightlike or near-lightlike speeds). If inflation is correct and the bulk of the matter in the universe is composed of baryons, it is fairly easy to show that the age of the universe must be $t = (2/3)H^{-1}$, where H is the Hubble constant, which relates a galaxy's distance to its apparent velocity of recession.

There is considerable debate concerning the value of H , a number that must be measured experimentally. H is usually written in units of kilometers/second/megaparsec. Since both kilometers and megaparsecs are distances, they can cancel each other out, so this is really just a rather perverse way of writing 1/seconds, the inverse of time. Gerard de Vaucouleurs of the University of Texas has consistently measured values of over 100 km/s/Mpc for H , but most investigators believe H is closer to 50 km/s/Mpc. There have been few claims for an H lower than about 45, and none of these estimates have been made in the last decade.

A Hubble constant of 50 km/s/Mpc translates into about 5×10^{-11} years⁻¹, so its inverse, H^{-1} , is approximately 20 billion years. According to the inflationary scenario then, the age of the universe would be $t = (2/3)H^{-1} \approx 14$ billion years.

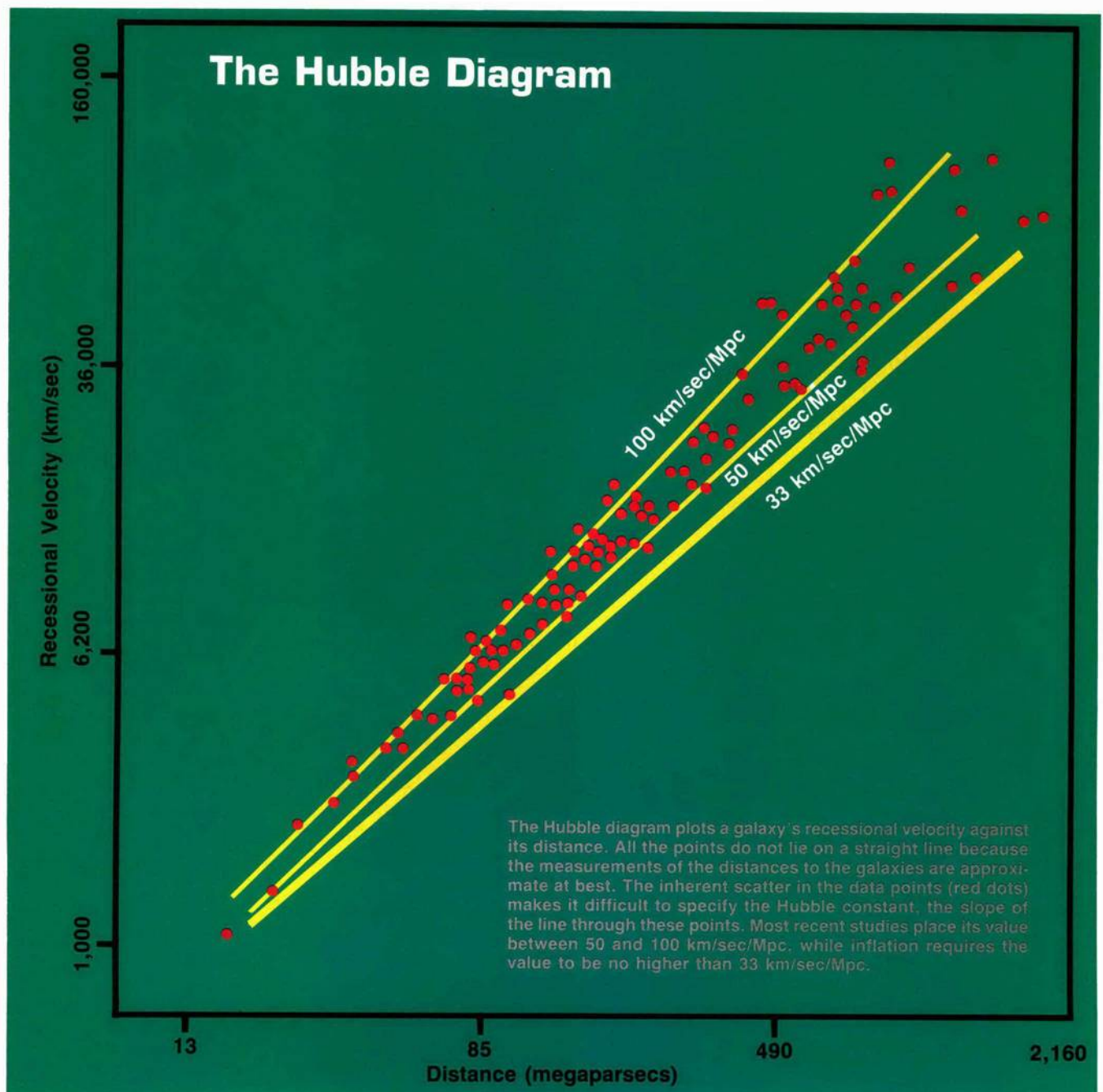
Recently, A. J. Penny and R. J. Dickens have studied the globular cluster NGC-6752 in Pavo and calculated its age at between 14 and 18 billion years. Notice that the lower limit of their measurement puts the age of this cluster equal to the age of the universe! This is implausible at best, since some time must elapse after the Big Bang before stars formed. Allan Sandage of Mount Wilson Observatory estimates this time to be about $(1/5)H^{-1}$. To accommodate NGC-6752 under inflation then, the age of the universe $[(2/3)H^{-1}]$ must be at least $t = 14 + (1/5)H^{-1}$ billion years. This only holds true if H is less than about 33 km/s/Mpc, which contradicts all recent measurements.

These calculations were performed for a universe dominated by baryonic matter. But what if the theoreticians are right and the yet-to-be-detected GUT and Susy-GUT particles dominate the mass density? These particles would be relativistic and behave like radiation, and they would cause the expansion of the universe to proceed at a faster rate than it would under the influence



Being within a factor of 10 or so of the critical density just seems too close to be coincidental. I'm confident that we'll find enough "missing mass" to raise the universe's density to the critical value, and this will help confirm the inflationary theory.

Inflation requires the universe to be at the critical density, yet this is directly contradicted by astronomical observations. The age of some stars in our galaxy seems to be greater than the age of an inflationary universe, and the Hubble constant derived from this age is lower than any recent measurement.



The Cosmological Constant



$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi T_{\mu\nu} - \Lambda g_{\mu\nu}$$

Reintroducing Einstein's cosmological constant into the equations of general relativity can get rid of the discrepancies you were just talking about and bring the inflationary theory back into agreement with observations.

The cosmological constant may resolve the age dilemma, but it also introduces a conundrum equivalent to the flatness problem, which inflation set out to solve. Essentially, you've gained nothing.



of baryons. It is easy to show that an inflationary, "radiation-dominated" universe has an age of only $t = (1/2)H^{-1}$. If $H = 50$ km/s/Mpc, the universe is only 10 billion years old and NGC-6752 would have been formed at least 4 billion years before the Big Bang — clearly an unlikely occurrence! To accommodate NGC-6752 in the manner we did above, H would have to be no larger than 21 km/s/Mpc, a value in serious contradiction with all evidence.

The Cosmological Constant

The only way to save inflation at this point without discarding the observations of stellar astronomy is to modify the equations of general relativity. One suggestion has been to reintroduce the infamous cosmological constant. The constant is an arbitrary number Einstein added to the equations to make his model of the universe static — which was how he believed the real universe should be. Once the expansion of the universe was discovered, he dropped the constant from the equations and labeled it "the biggest blunder" of his life. Nevertheless, if the constant exists and has a small value, its effect would be undetectable on the scale of the solar system, yet it would alter the expansion rate and lengthen the life of the universe sufficiently to remove the age contradiction in an inflationary universe.

But it turns out that the cosmological constant is in effect the same as the vacuum energy density we discussed earlier. To assume that today's value of the vacuum energy density is small but nonzero raises additional difficult questions quite apart from the fact that no evidence for a nonzero value exists, except the need to solve the age problem. Specifically, from the viewpoint of GUTs, when the vacuum decays from its metastable state at the end of the inflationary period, there is no known reason why its energy density should drop to exactly zero, a very small nonzero value, or a very large value. If the energy density has a nonzero value, why is that number now so small it is undetectable?

This is no less a conundrum than the flatness problem that inflation originally set out to solve! By introducing the cosmological constant to avoid the age contradiction, inflationists merely swap the flatness problem for the vacuum energy density problem: why is the vacuum energy density so close to zero?

There is a second difficulty associated with resurrecting the cosmological constant: it is a *constant*. Through

Einstein's equations it influences the behavior of spacetime and of every particle in the universe; yet, since it is a constant, nothing influences it. Such behavior violates the fundamental concept of action and reaction — a sound principle to demand of any theory because any entity that can affect another entity should itself be affected by this interaction. Einstein incorporated the concept of action and reaction into the theory of relativity by showing that spacetime is not absolute and immutable, but shaped by the objects within it. At the same time, the shape of spacetime determines how objects move. Indeed, Einstein's equations show how matter affects the geometry of the universe and vice versa. From this point of view, introducing the cosmological constant is a very retrogressive step.

Where Does This Leave Us?

A peculiar situation has arisen in cosmology. Over the last five years physicists have been hard at work on a theory that set out to resolve two problems that may not exist. This theory has no evidence to support it, and the one prediction it does make appears to be incorrect. To reconcile observations with this theory requires the existence of particles that have not been observed. Assuming these particles exist brings the theory into an even more serious conflict with astronomical observations, unless a further quantity is introduced that has also not been observed. This quantity presents a puzzle equivalent to the one the theory was originally invented to solve. And yet, because the theory is pretty in a mathematical sense, many theorists have embraced it and chosen to disregard these issues.

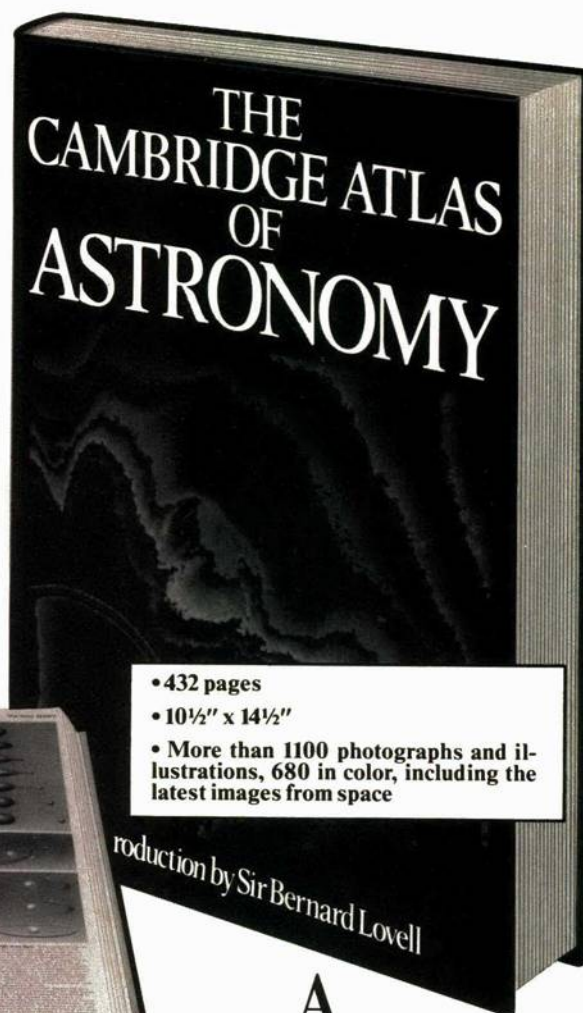
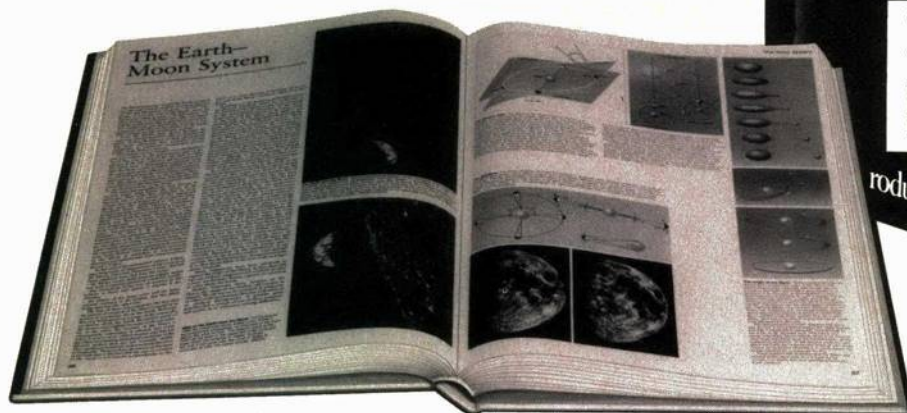
It is too early to make a conclusive judgment on inflation, which is, without argument, aesthetically pleasing. But there can also be no argument that cosmology is approaching the frontier where science is no longer based on experimental evidence and makes no testable predictions. Once this border is crossed, we have left the world of physics behind and have entered the realm of metaphysics.

*Tony Rothman received his Ph.D. from the Center for Relativity in Austin, Texas, and has done post-doctoral work at Oxford, Moscow, and Cape Town. He is the author of several books, the most recent being *Frontiers of Modern Physics*. George Ellis is a professor of applied mathematics at the University of Cape Town and is co-author, with Stephen Hawking, of *The Large-Scale Structure of Spacetime*.*

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Astronomy 2/87

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ASTRONOMY Forum

A Child's Perspective of Halley's Comet

One evening in early January 1986 I decided to set up my 4-inch reflector and show my friends Halley's Comet. Little did I know what I was in for! One of my friends is a teacher and he invited his entire school to come and have a look.

I arrived at my viewing site just after sunset, allowing myself more than enough time to set up my scope and find the comet. Or so I thought.

As I was setting up, two seven-year-olds materialized and started bombard-

ing me with questions and comments.

"How big is your telescope? How much did it cost? What can you see? What's a star? I have a friend who has a telescope. You can see right inside the Moon with it. Is that Venus?"

"No, it's Jupiter."

"No, it's not."

"Yes, it is."

"How can Jupiter be brighter than Venus? I saw Halley's Comet this morning."

"No, you didn't."

"I did so!"

It was starting to be a fun evening.

I bent over the eyepiece and began searching for the comet. One of the kids immediately elbowed me in the ribs.

"What are you looking at? Can I see it? Is it the comet?"

I ignored him and kept scanning. Suddenly my entire field of vision was filled with an immense, unidentified blob. My heart almost stopped. I looked up and found one of the kids peering into the tube. I gently pushed his head out of the way and continued searching.

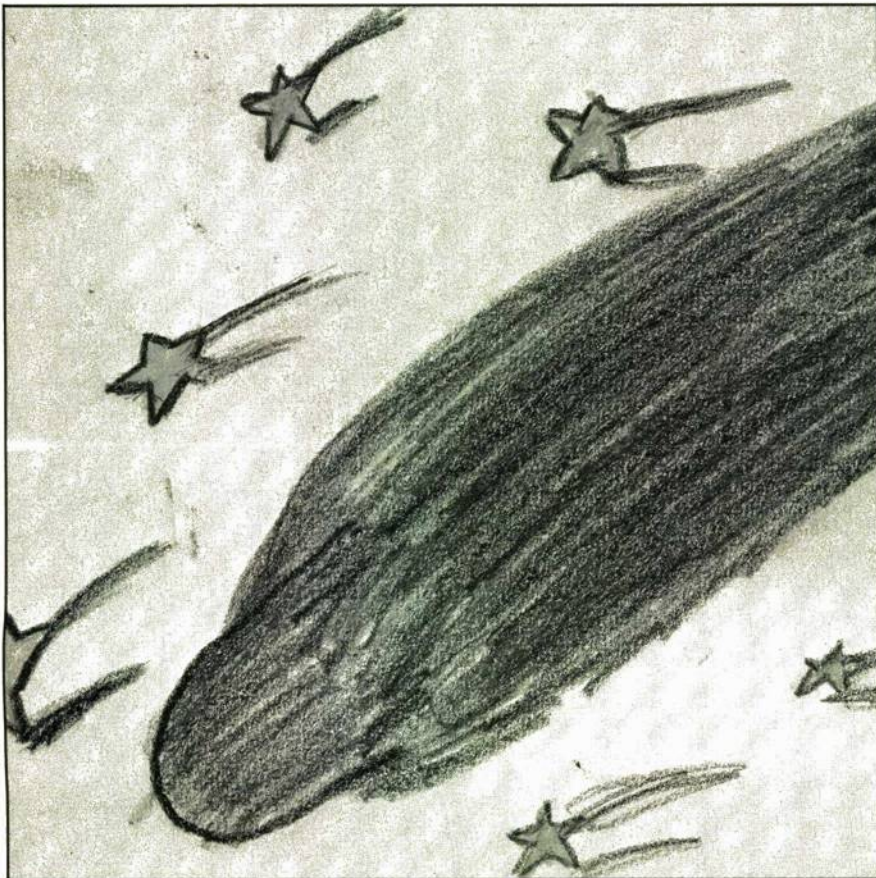
I was beginning to get desperate. The comet seemed to be playing hide and seek and the kids were getting on my nerves. More people were lining up. Come on, comet, where are you?

My two little friends were still firing questions and pushing and poking. I was tempted to pick out a star and leave the scope just out of focus. Would anyone blame me? Would these kids know the difference?

Finally someone showed up carrying binoculars. I grabbed them and quickly located the comet. Back to the scope. Down a little. A little more. Suddenly there it was! I started breathing again. Now it was just a matter of setting up an assembly line of eyeballs. Nothing could be easier.

I placed a box beside the telescope for the little guys to stand on so they could reach the eyepiece. The first thing I learned was that as soon as they got on the box they needed to put their hands somewhere for support. You guessed it — right on top of the tube.

I lined it up again. This time it was easy — just straight back up. After doing this six or seven times I realized that it would be a lot simpler to tell them not to touch the telescope. It worked. Now I had nothing to do but repeat the phrase, "That's it — the



Nicole Verville (Age 12)

Celestron® close-up news notes

THE 1987 CELESTRON AWARDS.

To recognize excellence in telescope making and astronomical education.

Starting at the 1987 Riverside Telescope Maker's Conference (RTMC), Celestron International will reward innovation and excellence in telescope making and astronomical education.

If you are involved in a school or public education project, demonstrate astronomy to the public, or have a bright product idea, you can be a winner!

Contestants will be awarded national recognition and an award for their achievement. Awards will be made by judges from Celestron under the guidance of an advisory panel of some of the top telescope users in the country.

There are four categories:

1. Best Public Communications Program. If you communicate to the public by demonstrating telescopes, teaching courses,

writing about astronomy/ telescopes, showing the sky to the public, building astronomy exhibits, or doing astronomical art, enter here! A Celestron award for the "Astronomical Educator of the Year."

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3. Best Astrophoto. Have you created an exciting film image of an astronomical event using Celestron equipment? You can be named "Astrophotographer of the Year" and have your work honored nationwide.

4. Best Astronomy Club of the Year. If you have an active, dynamic club or a special club project, you can enter your club in the

"Astronomy Club of the Year" competition. Tell us what your club does, how it does it and what success you've had and your club may be a winner!

How do you enter?

Get an entry blank from any participating dealer or Celestron International and describe your particular involvement in amateur astronomy. No purchase is necessary and everyone is welcome to enter (except Celestron International employees and their relatives). You may enter as often as you like, in as many categories as you wish. Entries will become the property of Celestron. (Product ideas are to be entered with a waiver). Our judges' decision is final. You may nominate another individual or group for their work as well as your own.

When are the awards?

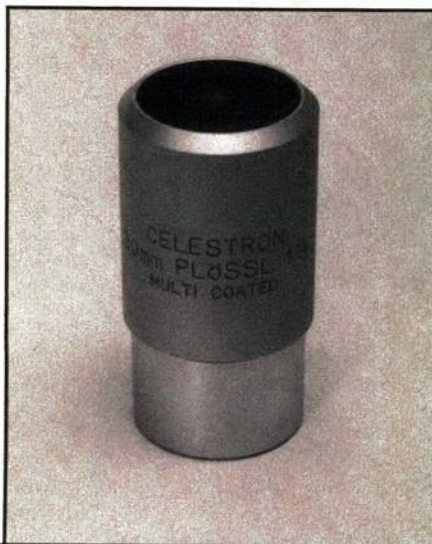
The 1987 awards will be announced at the 1987 RTMC in May.

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fuzzy thing," to everyone and adjust the alignment occasionally.

Things were going smoothly when I noticed a lady with three small children standing in line. She had a hold on two of them, but the third was running free. As soon as the loose one saw the scope he ran up to it and gave it a hefty push. Realignment time again. The pusher gave a repeat performance, and now we had a magnificent view of a streetlight.

It didn't take his mother long to get revenge. When it was the pusher's turn to look she held him parallel to the ground and said, "Look through here," and then bounced his eyeball onto the



lens three or four times. The little boy started screaming, "I see it! I see it! Put me down!" I think the comet might have been the last thing he ever saw.

A few minutes later another youngster had problems locating the comet. I kept asking him if he could see anything and he kept replying that he couldn't. I took a quick look and the comet was right in the center of the field of view. But the boy still couldn't see it. I bent down close to him while

he was looking and finally found out what the trouble was — he had both eyes closed! I told him to open his eyes. Not surprisingly he saw the comet right away.

Another child asked me about the big red thing he had seen in the sky a couple of weeks earlier. It was in the north and larger than the Moon. I was really stumped. I couldn't think of a single object that it might have been and I told him so. Then he said, "I think it was probably Santa Claus!"

The evening went much better than I had expected. More than two hundred people showed up and most of them went home happy and impressed by "Mankind's Comet." The weather cooperated and the comet obliged us by staying above the horizon until everyone had had a look at it. It disappeared into the west at about 8 p.m., and by then all the people had disappeared too. I was alone with my telescope and the silent sky.

The next day I got a nice surprise: a huge thank-you card from the school, signed by all the students. Many had added personal comments and drawn small pictures of comets, moons, and stars. The card is now hanging in a prominent place in my house. It's my special souvenir of the 1986 return of Halley's Comet.

Bill Johnston
Jasper, Alberta, Canada

guidelines on exactly what she wanted, and asked for the first two weekly columns. I told her I would try to conform to her style requests and sent in two more manuscripts. Three weeks later my first column was published: an introduction to amateur astronomy with my three friends — Venus, Jupiter, and Mars — in an accompanying drawing.

My column gets eighteen column inches, which works out to about two double-spaced, typewritten pages. I also include a three by five inch drawing that is redone by a newspaper artist using a computer.

The subjects of the column cover simple things like why the stars move, the differences between planets and stars, dark adaptation, averted vision, and the Tropic of Cancer. I've discussed over thirty constellations, the asteroid Vesta, the Andromeda Galaxy, the Moon illusion, and whether or not people act unnaturally during a Full Moon.

For the first few months I included the telephone numbers of the TAAA at the end of the column so interested people could call to find out about the club. After a while the calls were so numerous that we couldn't handle them all. They have tapered off, though I still get occasional calls or letters, most from people who want more information about something astronomical.

The column has certainly been successful, but we've had our share of bloopers as well. One typographical error concerned the "Summer Triangle of five stars," and in sketches Polaris was twice inadvertently placed in the northeast. I've had a drawing appear during the wrong week, and I missed the proper day of Algol's dimming.

Despite occasional problems, I've published a year's worth of columns and everything has gone pretty well. That qualifies me to offer some sage advice to potential astronomical writers everywhere.

- If you're interested, try your hand at astronomical writing. You have nothing to lose.
- Try to get your astronomy club to support the project with volunteer time. This helps widen your information resources and gives you moral support.
- Keep the column simple. Most people don't own a telescope, and though NGC-4565 may appeal to you, it isn't likely to appeal to most readers. Finding Orion's belt is a major triumph for many people. You are writing for them.
- Don't try to explain too much at once.
- New readers will be present each week. It is important that each

How to Teach (and Learn) Astronomy? Write a Column!

I've learned a great deal about astronomy from the "Under Dark Skies" column in the Tucson Sunday paper. I know, for example, why the Harvest Moon occurs in the fall, how to find Uranus, and that Beta Lyrae and Algol are bright eclipsing binary stars. Others have also learned from this column, which is sponsored by the Tucson Amateur Astronomy Association (TAAA), and it seems to be a popular fixture in the local media. That's good. Amateur astronomy needs good press. And besides, I write the column.

If you're thinking that I've been an amateur astronomer for twenty years and have professional writing experience, you're wrong. I've always been interested in teaching and writing but have only recently begun exploring the sky with my 8-inch SCT. I have joined both the TAAA and the American Association of Variable Star Observers. These are my only qualifications.

How did I get the idea for doing a column? There were three reasons: Venus, Jupiter, and Mars. While observing them during the late summer of 1984, I wondered how many others also saw them but perhaps didn't fully

understand what they were.

So I took matters into my own hands. At the next meeting of the TAAA I proposed that the club should sponsor a column on astronomy in the *Arizona Daily Star*, the paper with the largest circulation in Tucson. The club members and executive committee agreed that it would be productive and allowed me to write the column as the club's representative.

I wrote to the newspaper, which didn't answer. After three weeks of waiting, I called the paper. I was routed through several departments but finally got to speak with the feature editor. She wasn't certain that she would be interested. I did my best to explain the usefulness of such a column while stifling the urge to point out how much space the paper devoted to astrology every day.

She finally said that she would be willing to look at a sample column. I thought that was a fair agreement and sent along three articles on various subjects in astronomy.

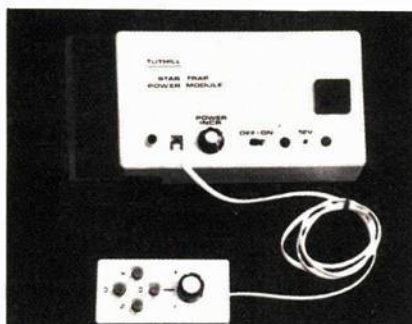
After three weeks, and to my utter amazement, I received a letter accepting the column. A few days later the feature editor called, offering

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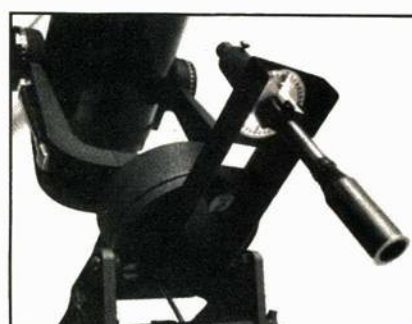
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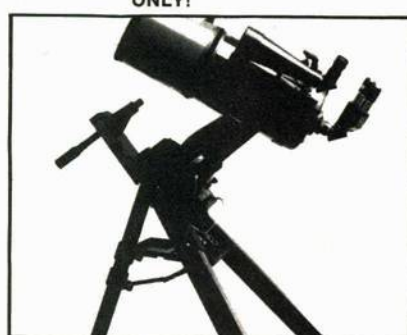
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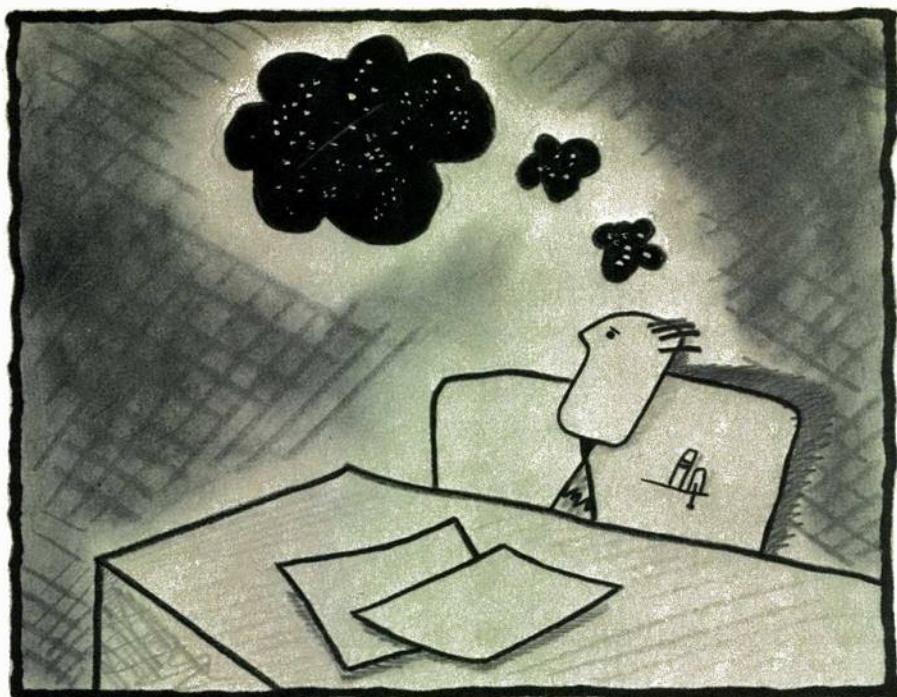
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column stands by itself. Those who wish an ongoing source can always consult a textbook.

- Devise a good opening line each time. That is your hook, your advertising. Rather than: "Look up in Virgo near Tau Virginis tonight and you can see Vesta," start with: "If you thought that the only asteroid you'd ever see is in a video game arcade, read on. This week, with binoculars, you'll see a real one!"
- Avoid planisphere drawings of the entire sky. They are fine for interested amateurs, but not for beginners. Show one area in detail. One format that has proved popular is showing bright stars and planets over the horizon in each cardinal direction.
- Double-check facts and spellings. Once I didn't recheck the spelling of Spica. I was wrong; it has no "k". It's a very uncomfortable feeling to open the Sunday paper and see a mistake in a column headed with your name!
- If you start a column you are committed to see it through. It's better not to start than to start and give up.
- While amateur astronomers may know the truth about light pollution, UFOs, and astrology, tread carefully on controversial subjects. Light pollution is an emotional issue. I have handled it thus far by saying that "stars are delicate creatures and many will disappear if house or city lights are too bright." Wait until you're secure before tackling controversial issues.

Finally, a note to the serious student of astronomy: If we get the general public to appreciate the night sky, we'll have a better chance of enlightening people about light pollution and astronomical research. More importantly, we'll avoid a real tragedy: people who grow up without appreciating the beauty of the night sky simply because no one told them how to see it.

Michael S. Smith
Tucson, AZ

The Case against Mars

Mars. The very name of the solar system's fourth planet strikes a special chord in the thoughts and feelings of twentieth-century man. Despite its fiery orange-red color, which prompted the ancients to name it for the god of war, this nearby planet has frequently been considered a likely place for life.

Toward the end of the nineteenth century, a Martian frenzy gripped the public. Fueled largely by Percival Lowell's observations of an extensive network of Martian "canals," the obsession with the planet contributed

to the panic caused by a fictitious radio report in 1938 of an imminent Martian invasion.

As our technology and understanding improved, the obsession with finding life on Mars reached a higher level. In the 1970s unmanned spacecraft were sent to land on and analyze the Martian landscape, looking for a confirmation of some sort — any sort — of life. The result? Inconclusive at best.

Today the Martian frenzy has reached a new level. The Red Planet beckons again, this time in the name

of international cooperation. A group of respected scientists, engineers, and politicians is calling for a joint American-Soviet manned mission to Mars, labeling it a stirring endeavor that would demonstrate just what the world's two superpowers could do if they put their heads together.

Such a mission to Mars may sound nice politically, it may even look nice on television, but it's a scientific dead end — at least for now. There's no way the Soviet Union and the United States, together or individually, would be able to justify such a trip on purely scientific grounds. Without the necessarily long-term commitment to establishing a permanent base on Mars, few reasons remain for sending men on a year-and-a-half journey to pick up a few rocks and take a few pictures on a planet that is beyond our ability to explore and develop.

Let's use common sense and not throw our entire space effort into a one-shot attempt to somehow capture the "human spirit" for all mankind.

I am not saying that the idea of cooperation in space between the superpowers is not commendable, exciting, and appealing. I also don't mean that we should abandon possible extensive unmanned exploration of Mars. But there exist several other, more effective ways we can develop and demonstrate cooperation in space. The two most obvious choices are an advanced space station and a lunar base.

The United States is already planning a large space station for Earth orbit and has set a target date for completion by the early 1990s. The United States has asked other nations to cooperate and even help finance the station. On the other hand, the Soviets have already placed cosmonauts in Salyut — their own rudimentary space station — for as many as 237 successive days. They have launched and are working on a much larger station called Mir, which will allow simultaneous docking of six vehicles. They have basic, practical experience in the social and psychological effects that extensive periods of spaceflight may have on men and women. Each country clearly has something to offer, and each has something to gain. The Soviets have the in-flight experience, and the Americans have the technology.

A lunar base, while certainly more difficult and expensive than a space station, would be a good way to carry on the lunar exploration begun by Apollo. The one-shot Apollo missions have left many questions about the Moon unanswered. A joint American-Soviet return to the Moon, with the ultimate goal of establishing a manned lunar station, would provide the world with all the cooperative missions it

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could stand. These missions would allow the same camaraderie that a joint mission to Mars would achieve, at a lower price.

There are road blocks, however, to any type of joint mission. Some American scientists, engineers, astro-

nomers, and politicians have at least a vague sense of uneasiness about such ventures. They remember the 1975 Apollo-Soyuz mission, when American and Soviet spacecraft docked in Earth orbit and exchanged pleasantries. The exchange of technology, they feel, flowed pretty much one way — from the Americans to the Soviets.

"There won't be any serious cooperative ventures between the United States and the Soviet Union until each country has something to gain as well as something to give."

All things considered, Apollo-Soyuz was purely a political act. Nothing has really come of it despite tentative follow-up plans involving a joint Shuttle-Salyut mission. East-West struggles on Earth have since overshadowed our only experience with a cooperative manned mission.

There is no question that joint missions carry tremendous potential. They make practical sense. A joint space station could offer almost unlimited scientific benefits for many decades to come. A mission to create a joint lunar base could re-establish serious investigation of the Moon and provide much scientific data for astronomers and geologists.

But just how politically feasible is a major joint space effort? The answer really depends on the type of mission. There won't be any serious cooperative ventures between the United States and the Soviet Union until each country has something to gain as well as something to give.

Curiously, Antarctic exploration bears a striking resemblance to space exploration, and studying it offers a picture of what may happen in space. The Soviet Union and the United States, as well as other nations, have

for years enjoyed a cooperative, non-aggressive presence in their scientific bases on the Antarctic continent. The Antarctic has probably been peaceful for so long because national bases were set up pretty much for scientific research.

Space exploration has already allowed technologically-advanced nations on Earth to exploit space resources, like geosynchronous orbits. Competition among nations for these limited, "stationary" positions above Earth could be one step that leads to serious attempts at political control in space.

The United Nations has already considered many of these problems and has begun establishing a series of international space laws. These laws are far from perfect, however, and the United Nations has little enforcement power. The ownership of celestial bodies is still pretty much an unanswered question, no matter what types of agreements have been made at the United Nations.

Will a cooperative space mission occur before other political forces destroy the possibility of such an intriguing project? Will common sense prevail and enable us to plan for an international space station or a permanently manned base on the Moon? Time is running out.

Carl Sagan, president of the Planetary Society, a pro-Mars mission group, has pointed out that 1992 holds a special meaning for Soviets and Americans. That year marks the seventy-fifth anniversary of the Russian Revolution and the five hundredth anniversary of the discovery of America. What better year, as Sagan and others have suggested, for launching a cooperative mission?

Ray Grasshoff
Austin, TX

'How Much Is That Comet?'

During the winter of 1985-86 I had the good fortune to run the campus station of the University of Pennsylvania's Flower and Cook Observatory in Philadelphia. The observatory station, located on the roof of our building, features an 8-inch Alvan Clark refractor. As a graduate student in the Department of Astronomy and Astrophysics, I was allowed to open the observatory to the public so that

people could view Comet Halley.

Almost five hundred people from the university and the surrounding region showed up. Many were knowledgeable and enthusiastic, and I considered the whole affair quite a success. Along the way, however, I heard a number of curious remarks, some of which are printed below.

The Senior Citizen

"Do you see the comet?"

"Oh, my. Yes." Pause. "Now I can die."

I can't think of a good response to this one. If I had known the senior citizens would say that, I wouldn't have shown them the comet. How guilty I feel! However, other graduate students came up with wonderful responses, like: "The comet's really killing them up there tonight, huh?"

The Little Girl

"Do you see the comet?" I ask.

"Wow. Wow. WOW!" she beams.

"You see it?"

"No."

The Family Man

"It's been five minutes already, can't you find the damn thing?"

"Please be patient. I should have it shortly."

"Listen, just get any old thing and we'll tell the kids it's the comet."

Telephone Questions

"Why isn't the observatory open during the day?"

(Too many good TV shows.)

"Is this the Astrology Department?"

(Sometimes I think so.)

"How do you get up to the observatory?"

(Suction cups.)

"Are you in charge of the comet?"

The Opportunist

"That fuzzy splotch? I was hoping to



see something more dramatic."

"Sorry no tail is visible. If you want to stay, I'll show you some objects that you may find more interesting."

"Nah. I have to go."

The Little Boy

"Wow. This looks like a big gun."

"It's a telescope. In some ways it's more powerful than a gun. Do you see the comet?"

"Yeah. Can we shoot it down?"

The Business Man

"How much is that telescope worth?"

"I don't know. At least ten grand."

"Yeah? How much is the comet worth?"

"It's priceless."

"No. Really. How much?"

Pause. "How much do you have?"

Robert Nemiroff
Philadelphia, PA

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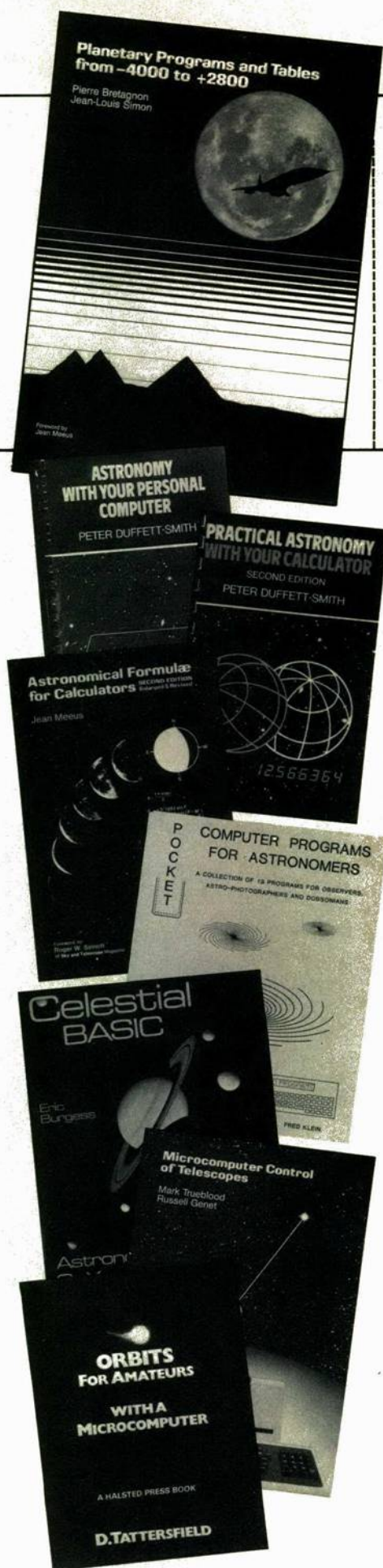
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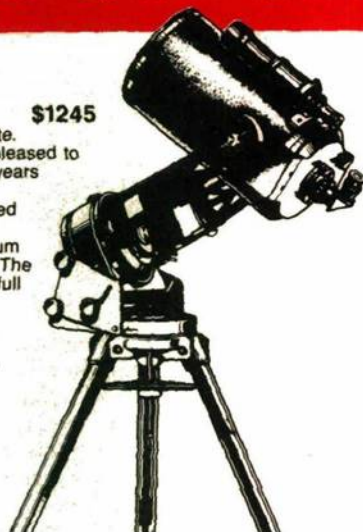


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In Focus

Inspiring Occultation

Sir / I appreciated the information you provided about the timing of the July 18 occultation of Antares by the Moon (The Backyard Astronomer, July 1986).

Though the results of my observations were not satisfactory for use by the International Occultation Timing Association because of inadequate equipment, the experience was quite enjoyable, and left me with a real sense of participation in an astronomical event.

Lee A. Phillips
San Diego, CA

Another Dobsonian Convert

Sir / I have gazed through my first Dobsonian, and I believe!

I have been seriously observing deep-sky objects for about ten years. After logging over 500 objects, I realized that my 8-inch Schmidt-Cassegrain, though I dearly loved it, simply could not show fainter objects. Nor would it show any more detail in objects I had already observed. What to do?

Photography? Perhaps, but the idea of staring at some guide star for an hour or more, then hoping I hadn't screwed up my guiding or exposure, didn't appeal to me.

A bigger scope? Ideal! But what kind? A larger Schmidt-Cassegrain? Nope. Major money — my wife would divorce me. A large Newtonian? Possibly, but they tend to be long, heavy and, let's face it, expensive.

That left the Dobsonian, large and relatively inexpensive. Now I had always had the attitude that if a telescope doesn't have a clock drive, or at least an equatorial mount, it wasn't for me. But I was desperate — I had to have more light.

So I built a 13.1-inch Dobsonian and I used it for the first time this summer. Conditions were not great. The sky was clear, but the wind was blowing about 25 miles per hour. Under these

conditions my 8-inch Cassegrain would have been doing St. Vitus' dance. But the Dobsonian was rock steady; its images were clearer and brighter than any I had ever seen. During that first session I observed ten new objects plus some of my old favorites, like M-11 and M-13, which had never looked so magnificent. The movement was not "butter-smooth," but it wasn't bad. And I had light!

Russ McDonald
Livonia, MI

Copyscope Modifications

Sir / Hats off to Ken Bird for his fine copyscope article ("Building a Copyscope," Equipment Atlas, May 1986). I have made several of his scopes thus far, and they have been big hits as gifts.

I made a couple of modifications to the copyscope I built, which might be of interest to other copyscope builders. First I made a finder scope from a 9-inch length of 3/4-inch PVC pipe. The pipe is secured to the dew cap by hose clamps.

Second, instead of using a 1x2-inch piece of wood for the tripod adaptor, I found that a 6-inch piece of 1x4 stock is even more effective. I threw away the metal retainer and put the U-bolt right through the wood. The wider stock makes for a nice snug platform and holds the whole works together beautifully.

Al Schumann
Springfield, VA

Northern Hemisphere Bias

Sir / In "On the Road with Comet Halley: Australia" (Forum, September 1986), Joel Gendler described his viewing experiences in the Southern Hemisphere: "I saw Leo upside down in the north and watched Mars and Saturn rise on the wrong side of the sky." If he had been standing on his

feet, he would have seen what we all see in Australia — Leo *right side up* and Mars and Saturn rising on the *right* side of the sky.

Later in the article Mr. Gendler said that setting up the star tracker on the South Celestial Pole for photography was a "trying task." I sympathize with him, and I'm sure he can now appreciate the difficulty we have with some magazine articles and instruction manuals that tell us to align our telescopes on Polaris. This is indeed a trying task, especially at latitude 33° south!

On the other hand, I am extremely grateful to see the Southern Sky and Sky Dome published in the Southern Hemisphere editions of ASTRONOMY.

Allan J. Elliot
Gateshead West, New South Wales,
Australia

'Disappointing Performance' of Comet Halley

Sir / Many amateurs, especially those in the Southern Hemisphere, were surprised by complaints that Comet Halley failed to "perform" according to expectations, because Halley put on a tremendous display when observed under good conditions.

During March 1986 the comet was a stunning naked-eye sight with a coma between magnitudes 2 and 3 and a tail traceable past 10°. Even from the suburbs of Brisbane, which has a population of over 1 million, the tail of the comet was very plain to the naked eye, especially when the comet attained a high altitude.

Although the tail became less prominent in early April, the total brightness of the comet's head was still about magnitude 2 and it appeared as a bright horn-shaped mass to the naked eye. Once the Earth moved toward the comet's orbital plane, Halley's dust tail was even brighter. By the lunar eclipse on April 24, tail

lengths reached from 20° to 40°, although the comet's head had faded to magnitude 3.5.

By the first week of May the coma had a magnitude between 4 and 5 and the tail remained visible to the naked eye, even from the outer suburbs of Brisbane. This last observation agrees with David Eicher's description in "Halley Brightens One Last Time" (Photography in Astronomy, August 1986).

The "poor performance" of the comet was due far more to poor viewing conditions than to the comet itself.

Terry Lovejoy
Shailer Park, Queensland,
Australia

Mythological Confusion

Sir / Early classical mythology did not directly associate Perseus with Pegasus, as explained in *Eye in the Sky* by Robert Burnham (November 1986).

Perseus was able to fly because he wore winged sandals given to him by Hermes, not because he rode the Flying Horse. It was Bellerophon who caught and rode Pegasus.

In the early seventeenth century Peter Paul Rubens combined the legends of Pegasus and Perseus when he painted *Perseus and Andromeda*. Even Shakespeare, writing at about the same time, refers to "Perseus' horse" in *Troilus and Cressida*.

Perhaps the similarity of their names and the nearby positions of the constellations named after them led to the confusion.

Jack Megas
Springfield, MA

— In early classical mythology Pegasus and Perseus were not directly associated, according to *Star Names: Their Lore and Meaning* by Richard Hinckley Allen and *Greek Myths* by Robert Graves. However, because Pegasus sprang from Medusa's blood — after Perseus decapitated her — Pegasus was the indirect result of Perseus' action.

Perseus did wear winged sandals, even in the Rubens' painting, so he already had the ability to fly and wouldn't have needed a flying horse.

More Computer Programs

Sir / I enjoyed "Eclipse Predictions on Your Computer" by Mark Whiteman (Gazer's Gazette, November 1986). Whiteman did a good job of explaining his program and the logic behind it. ECLIPSE.BAS seems like a handy program, although I haven't yet keyed it into my computer.

I would really enjoy seeing more computer programs in future issues of your magazine. I'm sure that many of

your subscribers either own a computer or have access to one.

Eric Rose
Cherry Hill, NJ

Expanding Horizons

Sir / Thank you for presenting "A Dedicated Dabbler Captures the Sky" by John C. Waugh and "Guiding Magnification for Top-Quality Astrophotos" by Barry Gordon (both in *Photography in Astronomy*, October 1986). I learned from both articles and wasn't too intimidated. I even understood the equations listed by Mr. Gordon!

More often than not I find myself "just looking" at some object instead of attempting to photograph it. Like Mr. Waugh, I am a dilettante — a man of many interests but master of none!

Your approach to astronomy and photography allows people like me to expand their horizons while remaining casual about it.

George J. Taylor
Elk Grove, CA

Contact's Grand Vision of the Universe

Sir / I wanted to avert any misconceptions about Carl Sagan's novel *Contact* that may have been raised by S. A. Blom's review of the book (*Astronomy Reviews*, November 1986). I don't take issue with the criticisms, but I feel that justice wasn't done to the book's message. Sagan has attempted to convey a grand vision of the universe, to express the beauty and awe that inspires the scientist. That Sagan deliberately compared this vision of the universe to a religious experience is very apt.

The stylistic shortcomings of this work are trivial in light of its content, which was entirely overlooked in the review. Those who read science fiction merely for entertainment will probably find more of the "fun of first contact" elsewhere, but anyone who has been stirred by the profundity of the universe will find *Contact* unforgettable.

Tom Springer
Austin, TX

Behind the Scenes

Watching for Pictures

Quite a few new ASTRONOMY readers have asked: "Where do you get those great photos you publish every month?" Of course, many of our pictures come from NASA and the big observatories, but most of the pictures we use in *The Backyard Astronomer*, *Gazer's Gazette*, *Photography in Astronomy*, *Equipment Atlas*, and *Eye on the Sky* are taken by our readers. From the pictures you send us we select those that show recent celestial events, illustrate new or interesting techniques in astrophotography, or capture the beauty of the planets, nebulae, galaxies, and other sky objects in striking or unusual ways.

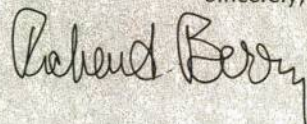
This month's *Gazer's Gazette* and *Photography in Astronomy* departments show how we put your photos to use. Last fall we received a lot of remarkably good photographs of the planets, so we started setting them aside for the article which appears in this issue. For *Photography in Astronomy*, we searched our photo files for the right images to illustrate the main points in the article; some of these pictures had been in our files for several years.

Submitting photos to ASTRONOMY is simple: write your name and address plus basic information about the photos themselves on

each print or slide, place them in a suitable envelope, and mail them to us. We appreciate a letter accompanying the pictures that gives the full technical details on how and when you took them. When photos arrive here we have to decide whether to keep them for possible use or to return them. We may publish those we keep immediately, or we may hold them in our files for possible future use. We can use color prints, color slides, or black-and-white prints.

While we're talking about astrophotography, I'd like to remind all of you astrophotographers (and potential astrophotographers, too!) about our monthly "Best Astrophoto" award. Each month we offer a \$100 prize to a particularly outstanding celestial image and publish it in our *Backyard Astronomer* department. You don't have to do anything special to qualify for our award — every picture sent to ASTRONOMY is a potential winner.

Sincerely,



Richard Berry
Editor-in-Chief

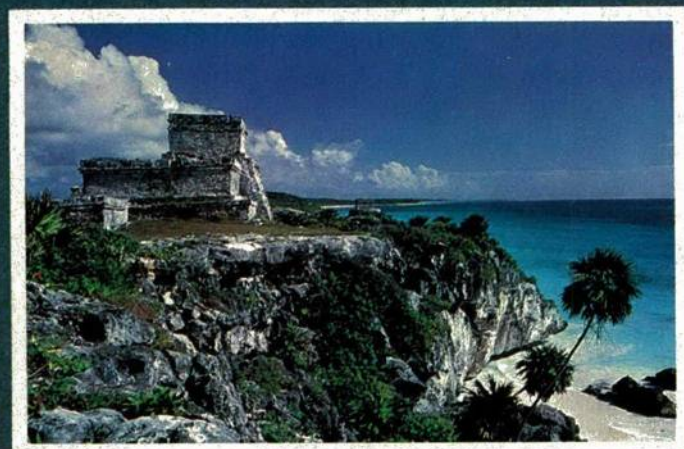
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by Richard C. Walter, Jr.

The concept of sidereal time is not new to most backyard astronomers, though many cannot take full advantage of its applications. Isn't there some easy way to calculate the sidereal time for any given moment? And then, once you've calculated it, isn't there some way to keep track of the sidereal time — like a sidereal time clock?

The answer to both questions is "yes" — providing you don't mind keying a short program into your personal computer and you have enough electronic know-how to modify a standard digital clock. For that matter, if you only have a personal computer, you're more than halfway to making practical use of sidereal time, since an ordinary clock will tell reasonably accurate sidereal time for a few hours.

Now, in case your memory's gotten a little soft, just what is sidereal time? Sidereal time is star time, the time the stars keep and, like most kinds of time, it is based on Earth's rotation. A sidereal day is the time our planet takes to spin once on its axis *relative to the stars*. This means that if you see a particular star on the meridian (i.e., due south) at a certain sidereal time, then exactly 24 sidereal hours later that same star will be back on the meridian.

There's one star that doesn't follow this rule: our own star, the Sun. Because the Sun moves eastward against the background stars as the Earth circles it, the Earth has to turn a little farther each day before the Sun crosses the meridian again. The average interval between two successive solar meridian crossings is one solar day. A solar day is 24 hours, 3 minutes, and 56 seconds of sidereal time.

Sidereal time is handy for astronomers because it's tied to the stars instead of to the Sun. For example, can you tell what stars are up at this very moment? If you know the sidereal time, the answer's easy. The sidereal time is the right ascension of the stars that are on the meridian. All you have to do is look at a sidereal clock and then consult a star chart to see which stars are highest.

Computing Sidereal Time with TIME.BAS

The *Almanac for Computers*, a book published by the Nautical Almanac Office of the U.S. Naval Observatory and distributed by the U.S. Government Printing Office, has all the formulae needed for a variety of serious astronomical calculations. (I used the USNO equations to write TIME.BAS.) To run the program, you must enter a starting date, your longitude, and the Universal Time. After you have entered this data, TIME.BAS prints a table

with the date, the Universal Time (UT), the number of that day in the year (DOY), the Julian date, the Greenwich Mean Sidereal Time (GMST), and the Local Apparent Sidereal Time (LAST) for each remaining day in the year.

GMST is simply the sidereal time on the prime meridian of the world in Greenwich, England. It's tabulated in the *Astronomical Almanac* for each day of the year at 0 hours UT, so you can check the output from TIME.BAS if you doubt it for some reason. LAST is what you want for your clock. It's the right ascension of the stars on your local meridian for the date and UT you've input. You'll also need to know your longitude. A degree of longitude is approximately 50 miles, so a minute of arc is somewhat less than a mile. You should be able to estimate your position to about 1 second of arc from a USGS topographic chart. Your public library may have charts for your area.

TIME.BAS was originally written for a TRS-80 Model I, but the version presented here is a version in BASIC that will run on most computers that use the BASIC programming language. However, BASICs do vary, so you should know your computer's BASIC well enough to recognize minor differences between this version and your computer's BASIC.



The LPRINT statement simply means "print this line on the line printer." If you would like to have the program output to the video screen, simply change all the LPRINTs to PRINTs. The program lines starting with "LPRINT CHR\$(27)..." send commands to the printer that tell Epson and many other dot-matrix printers to switch to a special extra-wide character set. These lines may be deleted; their absence will not affect the program.

Another part of the program that may need modification for your BASIC is the PRINT USING function. If your computer does not have this function or uses it in a different way, you must change PRINT USING to something your computer can do.

Another feature which may not be obvious is the "#" symbol used with the variables JD# and JD0# and several of the constants. This symbol tells the computer to make the variable double precision — 16 digits long. If your computer does not have this feature, omit the "#" symbols; this will reduce the accuracy of your

computer's output, however.

According to the *Almanac for Computers*, these formulae are good for a long time; the only exception is the Julian date algorithm, which doesn't give the correct result for the years 1900 and 2100. For most applications, however, TIME.BAS is good from 1901 to 2099.

Check to see that your version of the program gives the same numbers as those shown in the sample output. Remember that 00:00:00 UT corresponds to 7:00 p.m. EST or 8:00 p.m. EDT; 6:00 p.m. CST or 7:00 p.m. CDT; 5:00 p.m. MST or 6:00 p.m. MDT; and 4:00 p.m. PST and 5:00 p.m. PDT. Remember too that 0 hours UT is the beginning of the next day for Greenwich, England — so March 15 at 0 hours UT is March 14 at 7:00 p.m. EST in New York, New York.

A Sidereal Time Clock

One vexing problem with sidereal time is that it can't be displayed by standard solar clocks with any accuracy for more than a few hours. However, that may not bother you. If you don't mind a clock

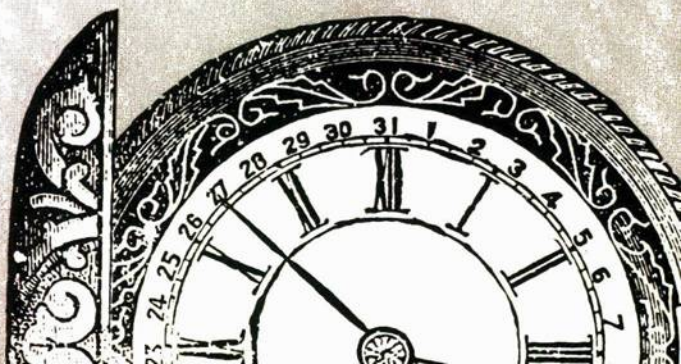
that's one minute in error, you can set a solar-time clock to the current sidereal time and the clock will be accurate to a minute for the rest of the night. But it's easy to go one step better: adjust a balance-wheel watch or clock to run fast by 3 minutes and 56 seconds per day; then set it to the current sidereal time. A minor problem with this is that most solar clocks display time in a 12-hour format, and sidereal time is in a 24-hour format.

There's an elegant high-tech route to sidereal time, however. Most digital clocks running on AC power use the 60-Hz line frequency to control the clock speed. The idea is simple: you cut the connection between the 60-Hz AC line frequency supplying your clock's integrated circuit and instead supply the signal from an oscillator operating at the correct frequency to run the clock at a sidereal rate. This sounds tricky, but there's an integrated circuit which, when used with a readily available quartz crystal, produces the correct frequency to drive digital clocks at a sidereal time. Furthermore,

TIME.BAS

```
100 PRINT "SIDEREAL TIME CALCULATIONS PROGRAM"
110 PRINT:PRINT "Written by R. C. Walter, Jr."
120 PRINT "Based on the USNO Almanac for Computers"
130 PRINT "Published in ASTRONOMY, February 1986"
140 PRINT:PRINT "To use this program:"
150 PRINT "Enter the year, month, day, your longitude,"
160 PRINT "and Universal Time. The program calculates"
170 PRINT "sidereal times for specified UT.":PRINT
180 INPUT "What YEAR do you wish (YYYY): ";K
190 INPUT "What MONTH do you wish ";M
200 INPUT "What DAY do you wish ";I
210 INPUT "Your LONGITUDE degrees ";LD
220 INPUT "Your LONGITUDE minutes ";LM
230 INPUT "Your LONGITUDE seconds ";LS
240 INPUT "W or E Longitude (W/E) ";W$
250 INPUT "What UTC HOUR do you wish ";UH
260 INPUT "What MINUTE do you wish ";UM
270 INPUT "What SECOND do you wish ";US
280 INPUT "Are your inputs correct (Y/N) ";Y$
290 IF Y$="n" OR Y$="N" THEN GOTO 100
300 W=I:EW$="East"
310 IF W$="w" OR W$="W" THEN W=-I:EW$="West"
320 ' set printer to extended print mode
330 LPRINT CHR$(27);CHR$(87);CHR$(1)
340 LPRINT "SIDEREAL TIME"
350 LPRINT CHR$(27);CHR$(64)
360 LPRINT "LAST for longitude ";LD;LM;LS;EW$
370 LPRINT:LPRINT "MM/DD/YYYY UTC DOY ";
380 LPRINT "Julian Day GMST LAST"
390 LPRINT
400 ' compute UTC in decimal hours
410 UT=UH+(UM/60)+(US/3600)
420 ' compute longitude in decimal degrees
430 LAM=W*(LD+(LM/60)+(LS/3600))
440 ' compute day of year
450 N=INT((275*M)/9)+I-30
460 N=N-INT((M+9)/12)*(1+INT((K-4*INT(K/4)+2)/3))
470 ' compute Julian Date for 0 hours UT
480 JD0#=367*K-INT((7*(K+INT((M+9)/12))/4))
490 JD0#=JD0#+INT(275*M/9)+1+1721013.5#
500 ' compute julian date at 0 hr UTC
510 JD#=JD0#+UT/24
520 ' compute Julian centuries from J2000.0
530 TO=(JD0#-2451545#)/36525#
540 ' compute Greenwich Mean Sidereal Time
550 GMST=6.697374560000004#+(2400.051336#*TO)
560 GMST=GMST+(2.58622E-05*TO*TO)+(1.002737909#*UT)
570 ' reduce GMST to 0-24 range
580 IF GMST>24 THEN GMST=GMST-24:GOTO 580
590 IF GMST<0 THEN GMST=GMST+24:GOTO 590
```

```
600 ' compute Local Apparent Sidereal time
610 LAST=GMST+LAM/15
620 IF LAST>24 THEN LAST=LAST-24:GOTO 620
630 IF LAST<0 THEN LAST=LAST+24:GOTO 630
640 ' break decimal GMST into hh:mm:ss format
650 G1=INT(GMST)
660 G2=INT(60*(GMST-G1))
670 G3=3600*(GMST-G1-G2/60)
680 ' break decimal LAST into hh:mm:ss format
690 L1=INT(LAST)
700 L2=INT(60*(LAST-L1))
710 L3=3600*(LAST-L1-L2/60)
720 ' print line for table
730 LPRINT USING "###/###/####";M,I,K;
740 LPRINT TAB(12) USING "###:###:###";UH,UM,US;
750 LPRINT TAB(22) USING "####";N;
760 LPRINT TAB(30) USING "#####.#####";JD#;
770 LPRINT TAB(44) USING "###:###:###.###";G1,G2,G3;
780 LPRINT TAB(56) USING "###:###:###.###";L1,L2,L3
790 ' february logic
800 IF M<>2 THEN 850
810 IF I=29 THEN 910
820 IF INT((K-4*INT(K/4)+2)/3)=0 AND I=28 THEN 890
830 IF I=28 THEN 910
840 ' "thirty days hath september..."
850 IF I=30 AND (M=4 OR M=6 OR M=9 OR M=11) THEN 910
860 IF I=31 AND (M=1 OR M=3 OR M=5 OR M=7) THEN 910
870 IF I=31 AND (M=8 OR M=10 OR M=12) THEN 910
880 ' step day number and loop back
890 I=I+1:GOTO 450
900 ' step month and set day to 1 unless end of year
910 M=M+1:I=1:IF M<13 THEN GOTO 450
920 INPUT "Would you like to do another run? (Y/N)";A$
930 IF A$="Y" OR A$="y" THEN 230 ELSE PRINT "Thanks."
940 END
```



many digital clocks give you the choice of a 12- or 24-hour format. Using the 24-hour format along with the new oscillator, you can build a sidereal clock that is accurate to within 5 seconds per year.

The oscillator used to replace the 60-Hz signal from the AC line is a very simple one. The main component is a MM 5369 Motorola integrated circuit. Most electronic parts suppliers sell this device for less than a dollar. The chip was manufactured for use with a 3.579545-MHz crystal (used as the color burst frequency in color TVs), to produce a 60-Hz frequency in battery-operated digital clocks. By making the crystal frequency just a little higher, you can produce a 60.16428-Hz frequency to drive a standard clock at the sidereal rate. The schematic shows there are only a few connections to make, and the parts layout is not critical. I used "perf board" and wire wrap for my prototype, but other construction techniques can be used.

If you don't have experience with

electronics projects and don't know anyone who does, tuning the oscillator will be the most difficult part, because you must use a frequency counter to set the frequency on pin 7 of the MM 5369 integrated circuit to 3.589300 MHz. Tuning is done by turning the variable capacitor "C2". When the oscillator's tuned, the chip produces a precise 60.16428-Hz output to drive the clock circuit.

The clock I converted to display sidereal time happens to be a kit I built many years ago. It uses a Motorola MM 5314 clock chip. I simply broke the foil leads on the circuit board and wired in my oscillator so that instead of feeding the clock a 60-Hz frequency from the AC power line, the clock chip receives the slightly faster clock pulse from the new oscillator. If you built a clock kit some years ago, as I did, or want to try your hand at modifying the clock from an old clock radio, make sure you know what you're doing before you start.

I ordered my quartz crystal from Jan

Crystals in Florida. It cost \$5.50 plus \$0.40 for first-class shipping and handling. Jan's phone number is (813) 936-2397, and the firm's address is 2400 Crystal Drive, P.O. Box 06017, Fort Myers, FL 33906-6017. Order a "rock" for a frequency of 3.589300 MHz, an HC/6U holder, 32-picofarad load capacitance, fundamental mode, non-oven use at 20° Celsius, and specify a tolerance of $\pm 0.005\%$ at this temperature.

With the aid of the sidereal time program, setting the sidereal clock correctly and checking its accuracy is a breeze. Instead of going outside on a cold winter night to keep checking the sky, you can simply look at the sidereal clock and know when your favorite deep-sky object is high overhead!

Richard C. Walter, Jr., teaches earth and space science for the Manheim Central School District in Pennsylvania and has been interested in electronics, ham radio, and computers for many years. This is his first article for ASTRONOMY.

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24391 Bytes free
SIDEREAL TIME CALCULATIONS PROGRAM

Written by R. C. Walter, Jr.
Based on the USNO Almanac for Computers
Published in ASTRONOMY, February 1986

To use this program:

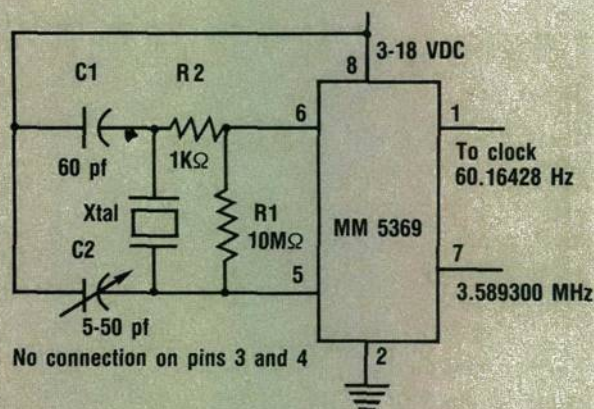
Enter the year, month, day, your longitude, and Universal Time. The program calculates sidereal times for specified UT.

What YEAR do you wish (YYYY): ? 1987
What MONTH do you wish ? 2
What DAY do you wish ? 1
Your LONGITUDE degrees ? 87
Your LONGITUDE minutes ? 54
Your LONGITUDE seconds ? 28
W or E Longitude (W/E) ? w
What UTC HOUR do you wish ? 2
What MINUTE do you wish ? 30
What SECOND do you wish ? 40
Are your inputs correct (Y/N) ? y

S I D E R E A L T I M E

LAST for longitude 87 54 28 West

MM/DD/YYYY	UTC	DOY	Julian Day	GMST	LAST
2/ 1/1987	2:30:40	32	2446827.6046	11:13:45.3	5:22: 7.4
2/ 2/1987	2:30:40	33	2446828.6046	11:17:41.8	5:26: 4.0
2/ 3/1987	2:30:40	34	2446829.6046	11:21:38.5	5:30: 0.6
2/ 4/1987	2:30:40	35	2446830.6046	11:25:35.0	5:33:57.1
2/ 5/1987	2:30:40	36	2446831.6046	11:29:31.5	5:37:53.7
2/ 6/1987	2:30:40	37	2446832.6046	11:33:28.2	5:41:50.3
2/ 7/1987	2:30:40	38	2446833.6046	11:37:24.6	5:45:46.8
2/ 8/1987	2:30:40	39	2446834.6046	11:41:21.2	5:49:43.3
2/ 9/1987	2:30:40	40	2446835.6046	11:45:17.8	5:53:39.9
2/10/1987	2:30:40	41	2446836.6046	11:49:14.3	5:57:36.5
2/11/1987	2:30:40	42	2446837.6046	11:53:10.9	6: 1:33.0
2/12/1987	2:30:40	43	2446838.6046	11:57: 7.5	6: 5:29.6
2/13/1987	2:30:40	44	2446839.6046	12: 1: 3.9	6: 9:26.1
2/14/1987	2:30:40	45	2446840.6046	12: 5: 0.5	6:13:22.6
2/15/1987	2:30:40	46	2446841.6046	12: 8:57.1	6:17:19.3
2/16/1987	2:30:40	47	2446842.6046	12:12:53.7	6:21:15.8
2/17/1987	2:30:40	48	2446843.6046	12:16:50.2	6:25:12.3
2/18/1987	2:30:40	49	2446844.6046	12:20:46.8	6:29: 9.0
2/19/1987	2:30:40	50	2446845.6046	12:24:43.3	6:33: 5.4
2/20/1987	2:30:40	51	2446846.6046	12:28:39.8	6:37: 1.9
2/21/1987	2:30:40	52	2446847.6046	12:32:36.4	6:40:58.6
2/22/1987	2:30:40	53	2446848.6046	12:36:33.0	6:44:55.1
2/23/1987	2:30:40	54	2446849.6046	12:40:29.5	6:48:51.7



Parts List for 60.16428-Hz Oscillator

MM 5369 oscillator IC

3.589300-MHz crystal

R1 10-megohm resistor, ¼ watt, 5%

R2 1,000-ohm resistor, ¼ watt, 5%

C1 60-picofarad capacitor
(high temperature stability)

C2 5- to 50-picofarad variable
capacitor

Tuning the oscillator: Place the input probe of a frequency counter on pin 7 of the integrated circuit. Turn C2 until the frequency reads 3.589300 MHz. When the oscillator receives 3 to 18 volts DC from the clock circuit and the output of pin 1 on the oscillator is connected to the 60-Hz input pin of the clock chip, the digital clock will run at the sidereal rate.

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Model 6600, right, shown with all standard accessories.
~~\$1400⁰⁰~~ **\$749**



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 Meade 8800 8" f/5 reflector, adjustable height tripod, slow motion controls, two eyepieces, \$1800⁰⁰ list \$949⁰⁰
 Meade #784 quartz drive/drive corrector, uses 4 C-cells, for 320/6600/8800, \$310⁰⁰ list \$199⁵⁰
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Shooting Galaxies from the Suburbs

by Clive Gibbons

Maybe you're as much of a deep-sky nut as I am. To me there's no greater thrill than capturing a distant spiral galaxy on film to marvel at on some cloudy night in the future.

The problem is that I also believe in the law of inertia, which keeps me close to the comforts and warmth of home. This may not bother you country folk who can step outside to a pitch-black sky, but what about us suburbanites? The sky might be darker sixty miles away, but who wants to travel that far, set up a complex telescope, load film into a fragile camera, and then realize that the star charts are at home on the dining room table?

If we stay at home, however, we suburbanites must compete with light pollution. But thanks to modern technology, this isn't necessarily an insurmountable problem for astrophotographers. It's possible to eliminate a great amount of scattered light by using a nebular filter, which blocks the majority

of streetlighting and allows the emission lines of $H\alpha$, $H\beta$, and ionized oxygen to shine through and record on film. Consequently, nebular filters perform beautifully on emission objects like the Orion and Lagoon nebulae, which emit most of their light in these select regions of the spectrum. But nebular filters don't perform well on galaxies, which emit their light over the entire spectrum.

Galaxies are difficult objects to photograph from suburbia. Veiled by light pollution, they are, with few exceptions, small, faint objects often located in star-poor regions of sky. Without a clever perspective on how to beat scattered light, it would seem that amateur astronomers interested in shooting galaxies from their suburban backyards are doomed.

Despite these problems, it is entirely possible to photograph galaxies from suburbia. Because most galaxies are small, a photographic system to record them requires a relatively long focal length. If

you employ a telescope with much less than about 48 inches (1200mm) focal length, you might have a hard time deciphering which objects are galaxies and which are stars in your photographs.

Because galaxies are typically faint, they are exceptionally difficult to spot through a camera's view finder; most are invisible. How do you photograph something you can't see? First, make sure that your finder scope and the telescope's main optical system are precisely aligned with each other. Then locate the galaxy in question in a good star atlas like *Sky Atlas 2000.0*. Now point the telescope, using the finder scope, to the precise starfield in which the galaxy lies. You'll discover how good your aim was when you see the developed photographs!

Not surprisingly, most galaxies are located far from the plane of the Milky Way, which means that finding a suitably bright star on which to guide may be difficult. You can't do much about this





Contrary to popular belief, galaxies can be recorded successfully on black-and-white and color film from light-polluted areas. The low surface brightness arms of Ursa Major's M-81 show in this 30-minute exposure made with a 20-inch f/5 reflector, VR 1000 film, and an LPR filter. Photo by Jack Newton.

Inset: A 40-minute exposure on 103a-F film with a fluorescent filter shows M-64's prominent dust lane and faint outer halo of nebulosity. The telescope used was an 8-inch SCT working at f/7. Photo by Clive Gibbons.

Opposite page: The graceful spiral arms of M-51 stand out in this photo made with an 11-inch SCT at f/7.6, hypered Tech Pan film, and a 45-minute exposure using a CC 30M filter. Photo by Clive Gibbons.

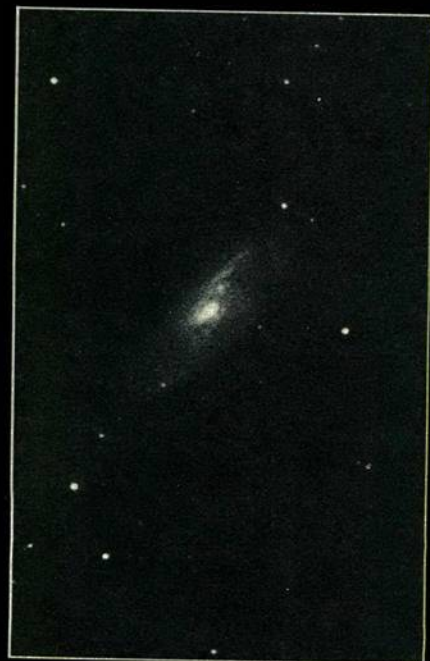
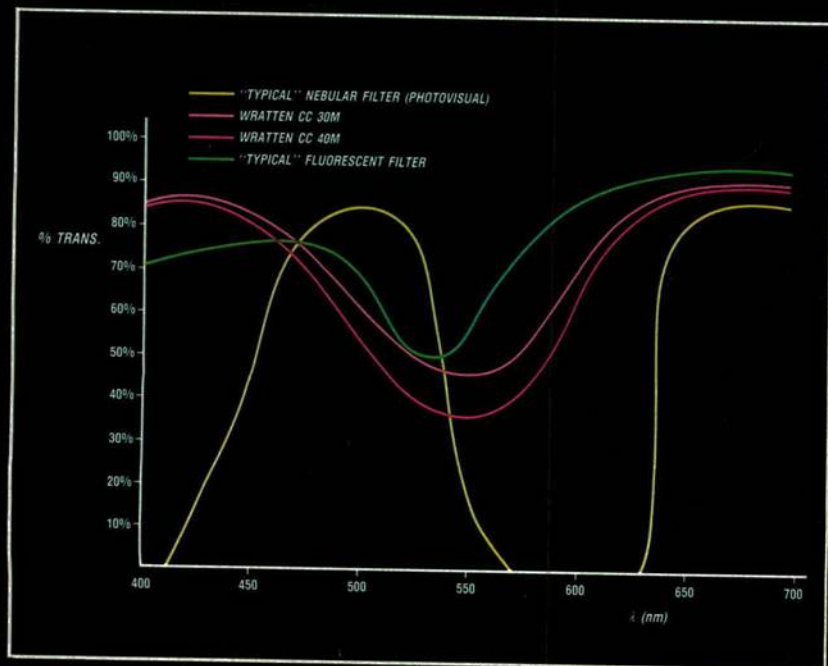


Pinwheel galaxy M-33's spiral arms, blazing nucleus, and tiny pinkish emission nebulae show in this 30-minute exposure made with a 17.5-inch f/4.5 scope, Fujichrome 400 film (developed as a negative), and an ultraviolet filter. Photo by Jack B. Marling.

Inset: Intricate details in the peculiar galaxy Centaurus A are revealed in this photograph made with a 17.5-inch f/4.5 reflector, 1600 ISO film, and a 30-minute exposure with an LPR filter. Photo by Mace Hooley.







Opposite page: A 30-minute exposure made with a 20-inch f/5 scope, VR 1000 film, and an LPR filter shows the contrasty network of dust clouds surrounding M-82's nucleus. Photo by Jack Newton.

Opposite, bottom left: This diagram shows the transmission curves of filters mentioned in the text. While the LPR filter offers the strongest "block" against light pollution, it also has the lowest luminous transmission, about 15 to 25 percent. The Wratten CC filters transmit about 50 percent of the light striking them, while the fluorescent filter passes over 70 percent of the light striking it. Diagram by Clive Gibbons.

Opposite, bottom right: A 40-minute exposure, made with an 8-inch SCT at f/7, 103a-F film, and a fluorescent filter, records galaxy M-106 in Canes Venatici. Photo by Clive Gibbons.

except persevere and try to find a star that's bright enough not to cause fatigue after a few minutes. (Guiding on faint stars strains the eye after a short time.) Users of off-axis guiders beware: the limited field of view means that guide stars are few and far between, and you may end up wishing you had a separate guidescope!

Suppose you have an operating telescope system, a camera, and the ability to find the right galaxy and guide on a suitable star. What type of filtration will allow you to record galaxies under light-polluted conditions? When we examine the light from a typical spiral galaxy, we see that the arms are bluish (from young, hot stars) and studded with pinkish emission nebulae, while the nucleus is distinctly yellow. Elliptical galaxies are entirely yellow because they lack young stars. The ideal filter would block streetlight emissions while allowing all other pertinent wavelengths to pass through. However, until such a filter can

be produced at a practical cost, we must compromise.

A fine compromise is a filter that passes a large amount of red and blue light but rather severely blocks the green wavelengths. Fortunately such a filter exists right in your neighborhood photography shop. It's called a Wratten CC30M and is sold in 2-, 3-, 4-, and 5-inch squares. These filters are composed of thin, lacquered gelatin and are quite fragile, but they can easily be cut and mounted on a standard glass filter for protection.

If you try a CC30M filter and find that you need even more protection from light pollution, try a CC40M filter. Wratten CC filters were originally designed to be used in enlargers to correct the color balance on prints, but that doesn't mean they can't be used as astronomical accessories.

The camera store probably has another filter useful for photographing galaxies under less-than-ideal skies. Normally used for taking photos of color film under

fluorescent light, a fluorescent filter is not quite as effective against light pollution as a CC30M or CC40M filter, but it is made of glass and usually can be purchased in diameters of 49mm and 52mm.

None of these filters is a strong light-pollution blocker; at best they'll reduce light pollution by about 50 percent. But in many cases that is enough to make a great difference in the final result of a photo showing M-31 or to save an otherwise hopelessly fogged negative.

Why even bother shooting galaxies under adverse conditions? Because galaxies are beautiful objects: rotating pinwheels, mottled edge-on streaks, or confused jumbles of knotty light. They are also a challenge to capture on film in our backyard telescopes.

Clive Gibbons is an active backyard astrophotographer living in Burlington, Ontario. His last article was "Some Reflections on Earthshine," published in the August 1986 issue.



NGC-4565 and its long, thin dust lane show up well in the 45-minute exposure made with an 8-inch SCT at f/6, 103a-F film, and a fluorescent filter. Photo by Clive Gibbons.

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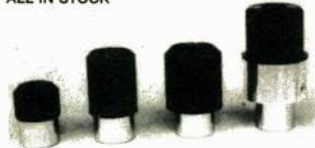


The "Flame Nebula" NGC 2024 in Orion. Also known as the "Christmas Tree" or the "Tank Trucks" nebula. NGC 2024 is seen best usually with either a LUMICON DEEP-SKY or UHC filter. Photo by Don N. Reiners, 16" f/5, 40 min. using hypered 2415 film and a LUMICON 2" EASY-GUIDER.

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40mm Wide-Field, "awesome," 65°	\$295
4.8mm Nagler, 82° field	\$150
7mm Nagler, 1 1/4" eyepiece, 82° field	\$185
9mm Nagler, 82° field, "the best"	\$225
11mm Nagler, 82° field, 1 1/4" or 2"	\$240
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20mm Nagler, 82° field, 2" eyepiece	\$340

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Sealmaster ball bearings, highly recommended add \$229

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6X30mm finderscope with brackets (\$56 list) \$42

8X50mm finderscope with brackets (\$130 list) \$96

Mercury in the Evening Sky

by Robert Burnham

The Wanderers

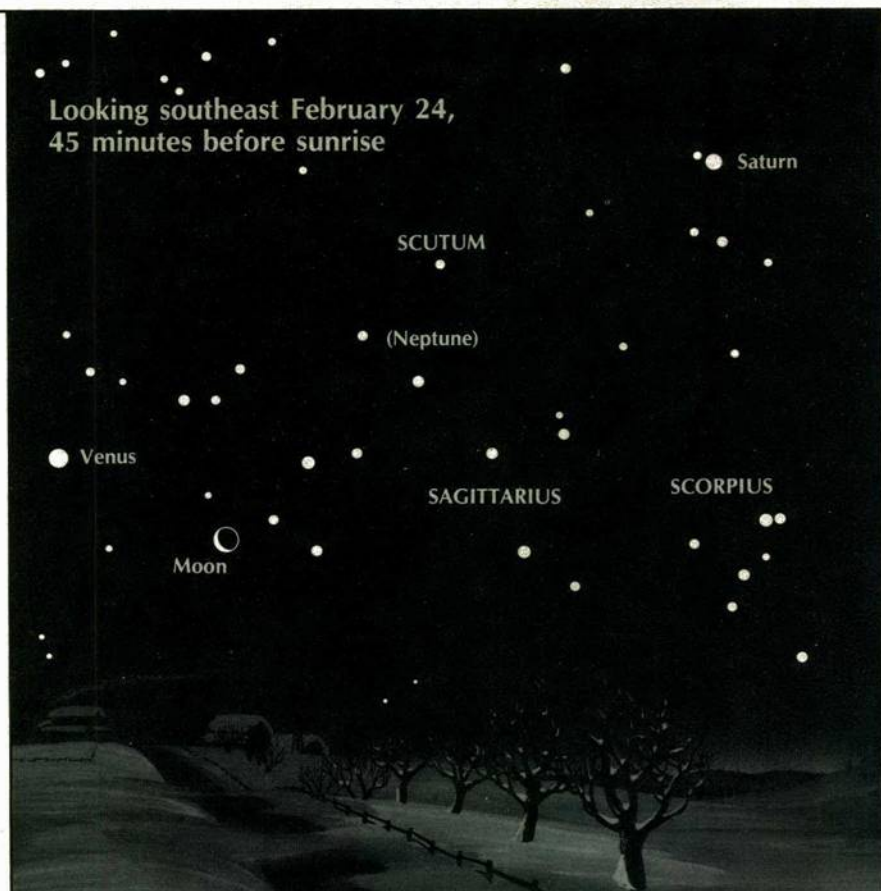
When the cold blue shadows of evening twilight deepen, you can see three planets in the western sky. Lowest of them is **Mercury**, the hardest of all the naked-eye planets to find. (Although the story goes that even Copernicus never saw Mercury, it is more likely that he never measured the celestial position of this fleeting little planet.) Mercury will become visible in late January and will be low in the southwest all month, except for a few days around greatest elongation on February 12. (See the diagram on page 52.)

Mercury is traveling eastward along the zodiac through Capricornus and Aquarius, constellations that feature no bright guide stars. As twilight's reddish glow fades in the west, look for a magnitude -1 amber dot of light the width of about four fingers above the southwestern horizon. Be sure you're looking from a site with as few horizon obstructions as possible.

Also, since clear evenings can be rare at this time of year, be prepared to snatch any viewing opportunity that presents itself. Consider keeping a pair of binoculars (and a copy of *ASTRONOMY*) in your car just in case the evening is clear when you come out of work. Even at best Mercury sets only ninety minutes after the Sun does, so don't dawdle. By the third week of the month Mercury is too low for viewing; on the 27th it passes between the Earth and Sun, moving into the morning sky thereafter.

To Mercury's upper left a much brighter planet beckons. This is **Jupiter**, gleaming white at magnitude -2.1. In dim Pisces, Jupiter is closing out a long viewing "season" as it dips nearer the Sun each day. By next month it will be gone, though it will reappear in the morning sky in April. On February 1, you'll see the

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.



crescent Moon very close to Jupiter.

To the upper left of Jupiter, at about twice its elevation, lies **Mars**, the Red Planet. (The color is actually more honey-amber than red.) Mars is about fifteen times dimmer than Jupiter, which is at magnitude 1.0. Mars is very distant from Earth at present — so distant that light would take almost thirty minutes to go there and return. Even a telescope won't show you very much of Mars right now.

Mars sets around 11 p.m. while Saturn, the next planet you can see, rises between 2 a.m. and 3 a.m. Rather than waiting up and braving the chill, set your alarm early and go outside an hour before sunrise. **Saturn** will be well up in the southeast, an ivory-white point of light near the stars of Scorpius. (Strange, isn't it, to view summer evening stars across a wintery landscape.) First-magnitude Antares, the Scorpion's eye, lies to Saturn's lower right; it has roughly Saturn's brightness but is ruddier in hue.

Below and left of Saturn the radiant "morning star" **Venus** steals the show — until late in the month when the waning Moon intrudes on the act. During February Venus' path takes it eastward, out of Saturn's vicinity and to the north of the Teapot asterism of Sagittarius. Magnitude -4.2 at present, Venus is losing its visibility day by day but will have a very long run low in the morning sky during the months to come: it won't be swallowed up by the Sun until July.

In winter our view of the Milky Way is toward its outer rim instead of its star-rich interior. In this predawn photograph, taken in August 1985 using a fisheye lens, Orion appears in the lower right corner, V-shaped Taurus is poised above Orion, and the bright Pleiades cluster is at right center. The stars Castor and Pollux are in the lower left corner and below them is Venus, reddened by atmospheric absorption. Embedded in the Milky Way to the left of Taurus is Auriga with its bright star Capella. Higher still, the constellation Perseus extends toward Cassiopeia, with the Double Cluster positioned in between. Left of center near the top is the bright spiral galaxy M-31 in Andromeda. Photo by Mace Hooley, who made this 30-minute exposure using Agfa 200 film.

The Starry Sky

When winter skies clear after a storm or when a blast of frigid Canadian air has swept down from the northwest, the stars shine especially brilliantly from a sky that seems cold and velvety black. They flash like diamonds and, while the sparkle means bad seeing for telescope owners, the stars are a joy for anyone viewing with the naked eye.

In mid-evening the southern sky from the horizon to overhead is filled with bright stellar gems. Foremost in brightness among all stars, and lying directly south around 9 p.m. tonight, is Sirius, the Dog Star. Sirius marks the head of **Canis Major**

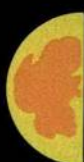
February Night Sky



First Quarter
February 5
11:21 a.m. EST



Full Moon
February 13
3:58 p.m. EST

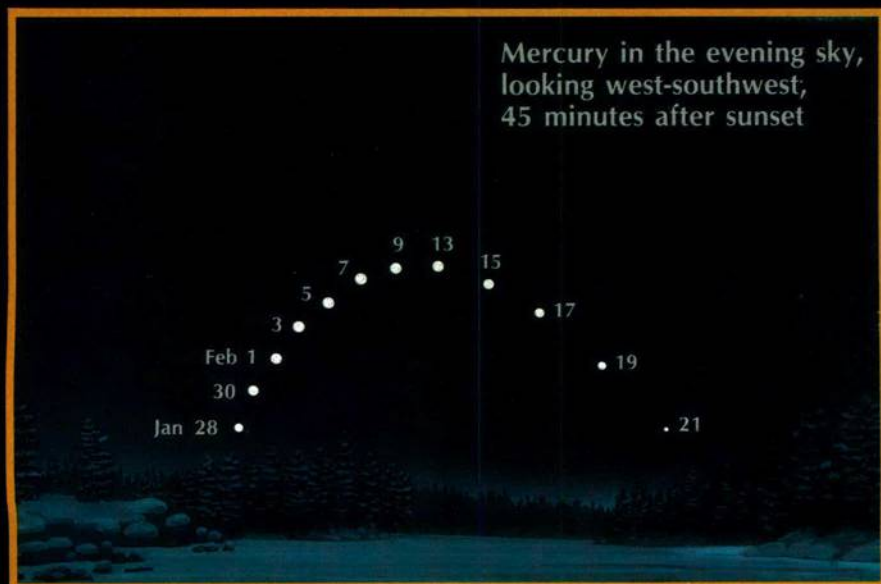


Last Quarter
February 21
3:56 a.m. EST



New Moon
February 27
7:51 p.m. EST

- 1st** Jupiter lies close to the Moon this evening. (It is occulted for viewers in the Southern Hemisphere.) Mercury is visible in the evening sky until roughly the 21st, but best visibility is in about two weeks.
- 3rd** Mars lies close to the Moon this evening. (It is occulted for viewers in southern Asia and parts of Africa.)
- 5th** First Quarter Moon occurs at 11:21 a.m. EST.
- 9th** The Moon is farthest from the Earth at 11:02 a.m. EST: 252,100 miles.
- 11th** Venus lies 1.3° north of Neptune, the latter visible only with a telescope.
- 12th** In the evening sky, Mercury is at greatest eastern elongation (and best visibility).
- 13th** The Moon is Full at 3:58 p.m. EST.
- 21st** Last Quarter Moon is at 3:56 a.m. EST.
- 22nd** The Moon passes 6° south of Saturn.
- 24th** Venus lies 7° north of the waning crescent Moon.
- 25th** The Moon is closest to the Earth at 10:54 a.m. EST: 226,041 miles.
- 27th** New Moon occurs at 7:51 p.m. EST. Mercury is at inferior conjunction and passes into the morning sky.



East

The
Star Dome
shows how the
sky looks at:

10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28

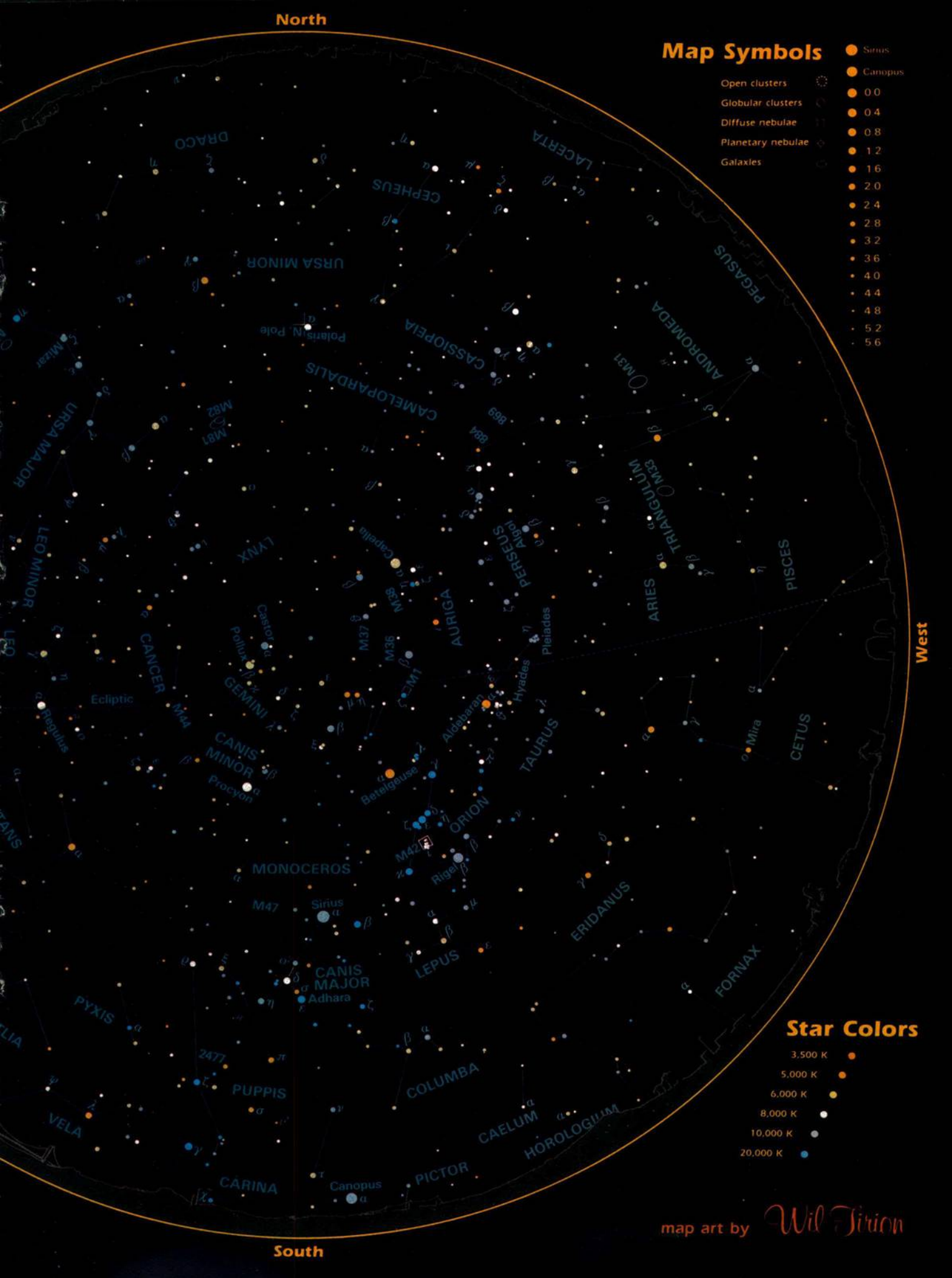
North

Map Symbols

Open clusters	
Globular clusters	
Diffuse nebulae	
Planetary nebulae	
Galaxies	
Sirius	
Canopus	
0.0	
0.4	
0.8	
1.2	
1.6	
2.0	
2.4	
2.8	
3.2	
3.6	
4.0	
4.4	
4.8	
5.2	
5.6	

Star Colors

3,500 K	
5,000 K	
6,000 K	
8,000 K	
10,000 K	
20,000 K	



South

map art by Wil Tirion



The shape of the aurora is dictated by Earth's magnetic field lines, which guide charged particles from the Sun as they encounter the upper atmosphere. This folded ribbon aurora was captured by Forrest Baldwin at Kiana, Alaska, using a 50mm f/1.4 lens, Ektachrome 400 film, and a 4-second exposure.

the Large Dog, who in mythology accompanied Orion on his hunts. Use the star map to locate the rest of Canis Major — it won't take much imagination to see a dog rearing on his hindpaws.

Above and to the right of Sirius strides the figure of **Orion** the Hunter. The three stars in a line forming his belt are unmistakable. To the upper left of the belt, on one shoulder, gleams the orange star Betelgeuse. The other shoulder holds a dimmer star (γ) named Bellatrix. Orion's knees are bright blue-white Rigel and Saiph (χ), the dimmest of the four "corner" stars. A sprinkle of dim stars below the center star in the belt indicates his sword.

Next to Rigel the River **Eridanus** winds its way south over the horizon, while the Hare **Lepus** scampers between Orion's feet unnoticed by the Hunter or his Dog. To the left of Betelgeuse one star stands prominently alone in a dim expanse: Procyon, the luminary of **Canis Minor** the Lesser Dog, which is a "new" constellation dating from the 1600s. (Canis Major dates back to antiquity.) Inside a corral made of Procyon, Sirius, and Betelgeuse, the Unicorn **Monoceros** prances impatiently, though he is too dim to be seen from most urban and suburban locations.

Above Procyon stand the embracing Twins of **Gemini**. Castor and Pollux mark the Twins' heads, while their bodies extend down toward Orion. The Twins are striding along the ecliptic, the imaginary track the Sun follows during the year. Tonight the ecliptic (marked as a dashed line on the star map) crosses the entire sky from due east to due west. East of Gemini the ecliptic passes through dim **Cancer** the Crab, just south of the fine binocular cluster M-44. Next comes **Leo** the Lion with 1st-magnitude Regulus in his heart. Below Leo (as you face east) part of **Virgo** the Virgin pokes above the horizon.

West from Gemini along the ecliptic we meet Orion's opponent, **Taurus** the Bull. His long horns meet in a "V" at the Hyades star cluster; 1st-magnitude Aldebaran is traditionally seen as his angry eye. Although the Pleiades cluster is often called the "Seven Sisters," most people can see only six stars with the naked eye; however, binoculars reveal dozens. One of Taurus' horns shares a star with the Charioteer **Auriga** (see Skylore). Capella, the brightest of Auriga's pentagon, is a yellow star similar in temperature to the Sun, though Capella is much larger.

For our final objects tonight, find a place with a very low view to the south. This is the best time of year to spot a giant

celestial ship that sails into these latitudes only rarely. The ship is the *Argo*, which carried Jason and the Argonauts on their quest. Extending south from beside Canis Major is *Argo's* Poop Deck, **Puppis**. Appropriately nearby is **Pyxis**, the ship's (anachronistic) Compass. Below Puppis and invisible from mid-northern latitudes are the ship's Sails, **Vela**, and its Keel, **Carina**.

In the Northern Hemisphere south of about latitude 35°, viewers can snatch glimpses of Canopus, the second-brightest star in the sky, about 40° south of Sirius. What an odd coincidence that the sky's first- and second-brightest stars should lie so near each other.

Skylore

Though we may think of stars as eternal, the patterns we group them into often suffer slow shifts in meaning. Few of these altered patterns have preserved their mixed origins better than Auriga.

Auriga is commonly depicted as a young man facing us. On his left shoulder sits the small she-goat Capella, while his left arm encircles three goat-kids: the stars Epsilon (ϵ), Eta (η), and Zeta (ζ). Yet he is holding reins in his right hand, and the name Auriga is Latin for chariot-driver. Ancient writers also called him *habenifer* (Latin for "rein-holder"), which is the name (when suitably translated) that the Greeks knew him by.

In classical times Auriga was usually identified with Phaethon, the son of Helios who one day tricked his father into letting him drive the Sun-chariot. Phaethon quickly discovered that the job was tougher than he could handle. Out of control he swooped back and forth — burning crops, drying up rivers, killing people. Even mighty Atlas, holding the world on his shoulders, had trouble maintaining a firm grip on the hot globe.

When Zeus saw what was going on he skewered the hapless lad with a thunderbolt. Phaethon's half-burned corpse fell into the River Eridanus, where Jason and his men (sailing the ship *Argo*) found it because of its foul stench. The Milky Way marks the scorched path of Phaethon's careening journey.

But if Auriga drives a chariot, why is he encumbered with goats? There isn't any

good answer, though it seems reasonable to assume that a goatherd-Auriga is older than a charioteer-Auriga, if only because people herded flocks long before they drove chariots. A minor legend ties Auriga to Erichthonius, a lame-footed Greek who supposedly invented the chariot, but an older Mesopotamian story says that when the goat-star (Capella) rises in the evening, the rainy season is about to enrich the summer-parched pastures.

When disentangling a messy skein of mythology, it often helps to trace a legend back to Sumeria, where history began five millennia ago. But this approach is useless here because even in Sumeria the two figures are already fused. A dead end then? Not quite.

In their book *Hamlet's Mill*, Giorgio de Santillana and Hertha von Dechend argue that during a long-past "Golden Age," when, as they put it, myth was still a vehicle for serious thought, the stars of Auriga occupied an important place in the sky.

First, they note that around 5000 B.C. the vernal equinox lay in Gemini and the Milky Way cut an impressive swath across the celestial equator there; during this same period, Auriga lay just north of the vernal equinox. Second, they find many mythological parallels in folklore to the Phaethon story, and these tales closely link the stars of Auriga, the errant chariot driver from the land of men, to the stars of Eridanus, which represent the world of the dead and Auriga's (and our own) final resting place.

Thus, while originally Auriga may indeed have been a celestial goatherd, he was moved about seven thousand years ago by the precession of the equinoxes to a place in the sky that was much more prominent, physically and intellectually, than he had ever held before. As a result Auriga changed into a Promethean figure symbolizing man's inability to control nature. The goats, his attribute from early Neolithic times, may have been retained simply because they helped ordinary men identify with him. Who can say?

In any case, the only constancy is change and precession's shift continues unabated. Thus today the Charioteer rolls along his tireless circuit of the Pole Star and retains only a ghostly link to this world and the ancients' hereafter, now far below the southern horizon.





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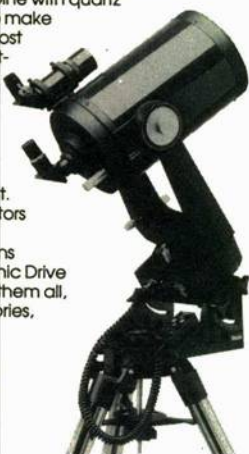
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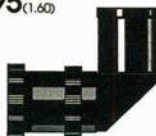
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The Planets of Summer

The summer of 1986 was a busy season for planet observers. Saturn, Mars, and Jupiter successively became bright naked-eye objects and compelling sights in telescopes in May, July, and September, respectively. Clear skies and balmy summer nights further encouraged observers to record the series of apparitions on film and in notebooks and sketchpads. The consensus of most serious observers is that, in terms of disk size and surface detail, all three planets put on a fine show. Mars and Jupiter were both nearer to Earth than they had been in many years, and Saturn's rings were inclined to their greatest extent since 1973. Even in small telescopes these three planets were magnificent objects.

The astronomical reason why last summer was a prime planet-viewing season is simple solar system geometry. As the planets revolve around the Sun, their positions are ever-changing with respect to one another. Periodically, however, the Sun, Earth, and a superior planet — one with an orbit greater than Earth's — lie in a straight line. From our vantage point on Earth we see the superior planet rising earlier each night until, when

it becomes aligned, it is *opposite* the Sun in the sky: the planet rises as the Sun sets and sets as the Sun rises. This configuration is known as opposition. The periods leading up to, during, and after opposition are ideal for observing a superior planet, because then it is fully illuminated by the Sun, visible all night, and positioned as close to Earth as it can be for that apparition, thus presenting a larger-than-usual disk.

Saturn was the season opener. Throughout April it grew in brightness and apparent size. Though it reached opposition on May 28, it remained a splendid sight in telescopes all summer. Its broad, reflective ring system, inclined 25.3° to our line of sight at opposition, and its nearness to Earth were largely responsible for making the planet so bright.

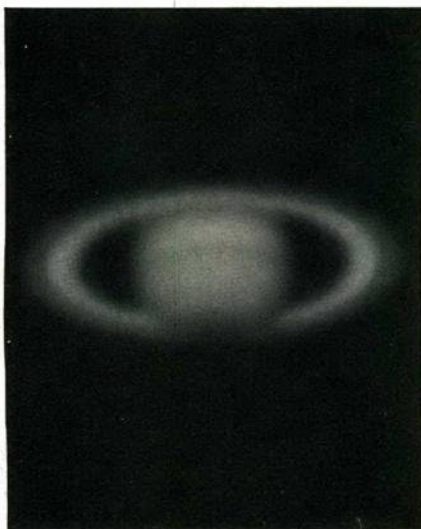
Mars followed Saturn, dramatically peaking in size and brightness in mid-July. For Northern Hemisphere observers Mars was visible low in the south as a bright, distinctly red "star" flickering furiously in the thick of the atmosphere. Despite the planet's ill-favored location, telescopes in middle to lower northern latitudes managed to reveal phenomenal detail as

Martian spring advanced and surface features darkened against the bright orange disk.

The planet show continued into August with Jupiter rising in the east just after sunset. Those who trained a small telescope on the luminary recognized Jupiter's flattened, sand-colored disk crossed with two dusky equatorial belts. Flanking Jupiter in an irregular line were the four Galilean moons, looking like tiny stars strung on an invisible thread. Large telescopes revealed a number of ephemeral cloud features on Jupiter's corpulent disk as well as changes in some long-lived features like the Great Red Spot.

Each planet presented such varied phenomena that few casual telescopic observers were disappointed. Serious observers, some using modest instruments, submitted reports, sketches, and

Saturn, Mars, and Jupiter as they appeared during their summer apparitions. Saturn photo by Kim Zussman, who used an 11-inch SCT; photos of Mars and Jupiter by Jean Dragesco, who used the 1-meter telescope at Pic du Midi Observatory, France.



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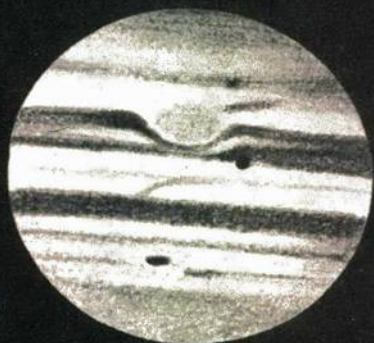


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1 Sketches can be as striking as photographs, as illustrated here by David L. Graham's drawing of Saturn on July 8, 1986. Graham used a 6-inch refractor. Note the dark shadow of the globe on the rings, the visibility of the Crepe ring, and the prominence of Cassini's Division.

2 On May 28, 1986, Jeff D. Beish recorded a dust cloud in the Hellas Basin on Mars.

3 An A.L.P.O. Jupiter report by Mark Daniels for October 7 (left) and 8 (right). In the sketch at left, a "rod" is shown in the north component of the North Temperate Belt. In the sketch at right, the streaks coming up from the south edge of the North Equatorial Belt are festoons projecting from "blue bases."

4 Martin Germano took this photo of Saturn on June 19, 1986, twenty-two days after opposition.

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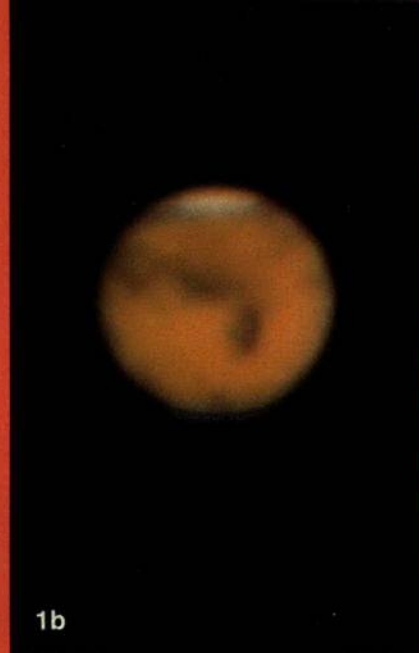
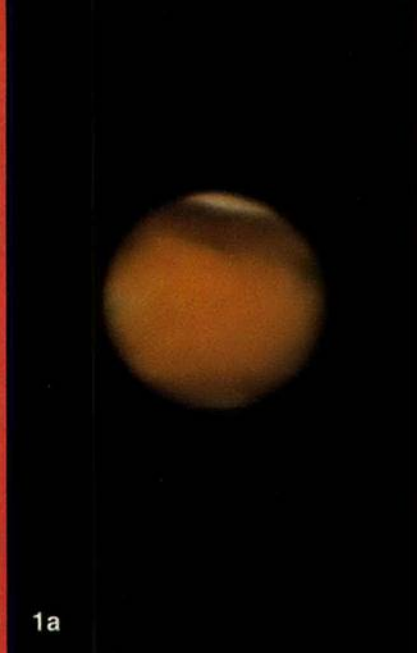
223
FLAG

1a Donald C. Parker photographed clouds over the Tharsis Ridge, a volcanic plain in the northern hemisphere of Mars on July 16, 1986.

1b The dark wedge-shaped plain Syrtis Major can be seen in this photo, taken by Parker on July 4, 1986.

2 The shrinking South Polar Cap of Mars revealed a major rift in the ice, known as the Rima Australls. The rift is seen in this August 15, 1986, sketch by Morimasa Nakajima as a thin, dark line across the Polar Cap.

3 Saturn's inner C ring and the globe's shadow on the rings can be seen in this photo taken July 20, 1986, with the 1-meter telescope at Pic du Midi Observatory in France, by Jean Dragesco.



photographs to the Association of Lunar and Planetary Observers (A.L.P.O.), an organization that compiles amateur reports of solar system phenomena from around the world. The proficient results of these observers prove that planetary observing is more than a satisfying pursuit for amateurs — it is also a good way for nonprofessionals to contribute to planetary science.

Saturn Shows Its Rings

As summer began, Saturn was competing with Antares in Scorpius for the title of brightest object in that region of the sky. Located just north-northwest of the brilliant deep-orange star, flaxen-hued Saturn reached magnitude 0.0 at opposition on May 28, just nine-tenths of a magnitude brighter than Antares. The planet's equatorial diameter reached 18.5", while the rings were 41.8" wide.

One would have to be jaded indeed not to marvel at Saturn's resplendent telescopic image. Even at low power the disk and rings stand out from the blackness of space with such presence that many first-time observers remark that the planet looks like "a little photograph."

The dimensionality is emphasized when

the globe's shadow is cast across the rings on the planet's "far side." During last summer's apparition, the shadow was most pronounced about two months on either side of the May 28 opposition, when Earth was angled away from the Sun-Saturn line. (This shadow is seen west of the planet before opposition and east of the planet after opposition.) The shadow looks like a narrow, dark angular void across the face of the rings just off the planet's limb. It can be seen clearly in the photograph on page 61, taken by Jean Dragesco using the 1-meter telescope at the Pic du Midi Observatory in France. The shadow is still quite narrow and closely follows the curve of the eastern (right) limb, which indicates that this photo was taken shortly after opposition (July 20, 1986).

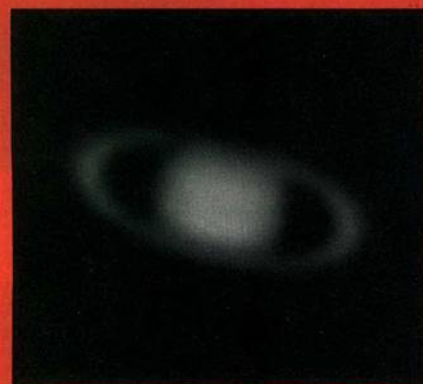
Being inclined 25.3° to our line of sight at opposition, Saturn's rings were favorably placed for observers. The three primary ring components are visible to varying degrees in most telescopes: the A ring (outermost), the B ring (middle), and the C ring. The B ring was, characteristically, the brightest ring during this apparition. It is the broadest ring and may

contain particles as large as a few meters across. The A ring is slightly darker because its particles are smaller and less densely distributed.

The diaphanous C ring is the most difficult of the three components, and it eluded many observers last summer. This ring is known as the Crepe Ring since it is nearly transparent and best seen silhouetted across the ball of the planet. Still, it is not easy to discern even in large telescopes. The Crepe ring appears in the sketch on page 59.

Between rings A and B is a narrow dark gap known as Cassini's Division. It has a reputation for being difficult in small telescopes, though not impossible, and, in fact, can be glimpsed in a 3-inch refractor during periods of good seeing. Cassini's Division was easy for most observers with 4- to 8-inch telescopes during Saturn's summer apparition.

However, another ring gap posed more of a challenge: the thread-like Encke's Division, positioned between Cassini's Division and the outer rim of the A ring. Encke's Division is narrower than Cassini's. You could lay about twenty Encke-size gaps in Cassini's Division, which





makes seeing Encke's Division — even during favorable periods — more of an exercise in subliminal perception. True to its reputation, Encke's Division was seen by very few Saturn observers.

Observing disk detail on Saturn is not easy either, even for those with 10- to 12-inch telescopes. Unlike Jupiter's atmosphere, which is agitated through convective processes, Saturn's convective activity occurs deep within its atmosphere, beneath a smoggy haze of ammonia cirrus clouds. Saturn is also twice as far away from Earth as Jupiter is and consequently exhibits a smaller disk, even at opposition. Observing disk features requires steady seeing, high magnifications, and, for best results, the image scale and resolving power of a long-focus 6- to 10-inch telescope.

Despite these obstacles, not every feature remained hidden from observers. Donald DeKarske of Colorado Springs noted on February 28, 1986, that the North Polar Region was slightly dusky and that the Equatorial Zone was bright. This is consistent with most photos and sketches made throughout the planet's apparition. In addition, the North Equatorial Belt, a shaded band running across the planet just north of the equator, was easy to see but "devoid of detail," DeKarske writes in his A.L.P.O. report. The North Temperate Belt, however, was "faint and difficult — darkened at extreme western limb."

Nearly five months later, on July 8, 1986, David L. Graham of Great Britain noted that the Equatorial Zone was the brightest feature and that the North Equatorial Belt appeared to be dark-edged. "Another belt was seen," Graham writes in his A.L.P.O. report, "which I take to be the [North Temperate Belt]. The planet got progressively darker towards the north pole, where it was darkest. The [North Tropical Zone] seemed to be of two intensities, being slightly brighter where it bordered the [North Equatorial Belt, north component]."

If these reports whet your appetite for planets, take note that Saturn comes to opposition this year on June 9. According to Julius L. Benton, Jr., A.L.P.O.'s Saturn recorder, the disk won't be quite as large as it was last year, but the planet should be brighter because the rings will be tilted at a slightly better angle.

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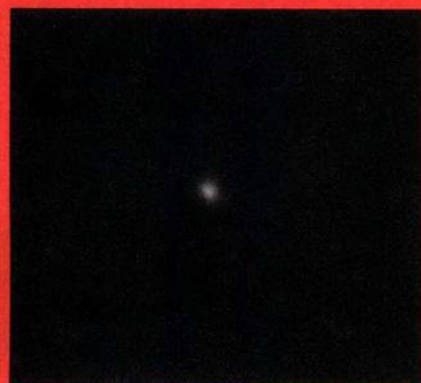
Mars: A "Perihelic" Opposition

Last June Mars could be found east of the handle of the Teapot asterism in Sagittarius. Observers had been watching the planet's disk swell all year, from a trifling 4.86" (slightly more than Uranus' size at opposition) in early January to 23" (nearly half the apparent diameter of Jupiter) by mid-July.

Veteran planet observers eagerly awaited the July 10 Martian opposition, because it was to be markedly superior than other recent oppositions of Mars. In fact, not since 1971 has Mars come as close to Earth (60.8 million kilometers) or been as bright (magnitude -2.7).

The reason only a select few of Martian oppositions are visually superior is the planet's orbit: it is more eccentric than Earth's, which means that it varies its distance from the Sun more than Earth does. Because of this, Mars lies at considerably different relative distances from the Sun and Earth at successive oppositions.

When Mars comes to opposition at its farthest point from the Sun (aphelion), the event is called an aphelic opposition. During aphelic opposition, Mars is at or



Geoff Chester and Richard Schmidt made this series of planet photographs on July 22, 1986, using the U.S. Naval Observatory's 24-inch reflector. The two planets at the far right are Uranus (the larger image) and Neptune, which came to opposition respectively on June 11 and June 26. All images are reproduced at the same scale so that the relative sizes of the disks reflect their apparent diameters.

near its greatest distance from Earth, and its disk is small and dim.

However, when Mars comes to opposition when it is nearest the Sun (perihelion), the event is called a perihelic opposition. During perihelic opposition, Mars is at or near its minimum distance from Earth and its disk is large and bright. Perihelic oppositions recur every fifteenth and seventeenth year after the last perihelic opposition. This last opposition was perihelic; the next will occur in October 1988.

The Martian disk I observed in my 8-inch reflector in early July was "watery" because it was positioned low in the turbulent atmosphere — roughly 20° above the horizon when it crossed the meridian, seen from 42° north latitude. Nevertheless, at 133x Mars loomed large in the field and the South Polar Cap was bright. The Martian atmosphere seemed free of the blanketing yellow-hued dust storms that characterized the 1971 perihelic opposition. A number of patchy dark features — most prominently Mare Tyrrhenum and the wedge-shaped plain Syrtis Major — were easily discerned.

The Mars reports submitted by A.L.P.O. observers were dominated by clouds, hazes, and brightness changes in surface features. Notable regions that exhibited change were Solis Lacus (known as the "Eye of Mars") and the South Polar Cap.

"The most spectacular change has been the darkening and enlargement of the Solis Lacus," write A.L.P.O. Mars recorders Donald Parker and Jeff D. Beish. "This feature, with its associated 'canals' and nearby dark areas . . . has much the same appearance as it did in 1911 and 1924. This year it has become the darkest feature on the planet."

The South Polar Cap exhibited several rifts, according to the reports received by Parker and Beish. One of the largest was the Rima Australis (Southern Fissure), seen August 15, 1986, by Morimasa Nakajima

of Yokohama, Japan. Such rifts in the ice are known to occur around the periphery of the Southern Polar Cap during perihelion, when the planet is nearer the warming influence of the Sun.

During July observers reported numerous white clouds near the Martian volcanos on the Tharsis Bulge, just north of the Martian equator. These clouds are best seen using violet and blue filters, which more efficiently pass the predominant wavelength of light reflected by the clouds, while blocking the orange light from the planet's surface.

Yellow dust clouds were observed on May 28 by Parker and Beish in the large, bright impact basin Hellas, located directly south of Syrtis Major. On June 29 low-altitude white clouds (not associated with dust clouds) were seen just east of Syrtis Major by Parker in Libya.

By summer's end Mars had retreated as quickly as it had advanced, its disk dwindling to roughly one-third its size at opposition. Still, observers with large telescopes continued studying the planet well into October, when its gibbous phase was quite apparent.

Observers are now looking forward to the 1988 Martian opposition, when the planet will be slightly closer to Earth with its southern hemisphere tilted over 20° in our direction. Parker and Beish are asking for good amateur observations of the planet during 1988 and are particularly interested in observations recording the initial phases of global dust storms, rifts in the South Polar Cap, and brightness changes in surface features.

The Changing Face of Jupiter

In late July and early August Jupiter lay in Aquarius (where it had been since February), rising above tree-top level an hour and a half after sunset. Even though it was still low in the sky, the shimmering image in my 8-inch reflector at 40x showed a generous-sized disk roughly 47" across. Higher magnification revealed

little detail, but the bloated face of the planet looked mottled, suggesting finer detail underlying the scintillating effects of Earth's roiling atmosphere.

In September, as Jupiter ascended higher in the sky after sunset, its North and South Equatorial Belts stood out sharply against the disk, though the southern belt seemed darker and more well-defined than its counterpart. The Red Spot was a blanching pink oval rimmed with darker material, which made the spot stand out well. There was also much coarseness in the temperate and polar regions of both hemispheres.

Jupiter was actually making something of a comeback last summer. Not only was its opposition disk size (49.6") greater than it had been in eleven years, but the planet was also riding higher in the ecliptic than it had since 1983. At a distance of 594 million kilometers, Jupiter was just 3 million kilometers shy of its minimum distance from Earth. The large, -2.9 magnitude disk was ripe for observing.

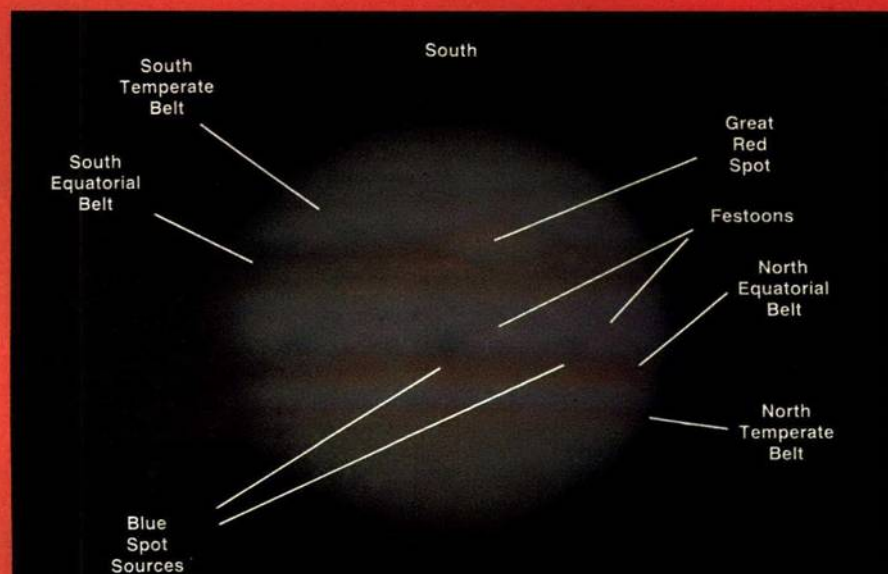
In June David Lindemann of Poughkeepsie, New York, wrote ASTRONOMY that on June 22 at 8:45 UT (4:45 a.m. EDT) he had seen an unusual "spot" that appeared attached to the southern edge of the North Equatorial Belt ("In Focus," November 1986). While making observations two mornings later, Lindemann noticed that the feature had developed into two spots "connected by a reddish-brown arch" that formed a loop.

Phillip W. Budine, a Jupiter recorder for A.L.P.O., informed ASTRONOMY that Lindemann's observations were confirmed by other observers. According to Budine, Lindemann was the first observer in 1986 to report the darkening of this feature, which was discovered in 1985 by Jose Olivarez of A.L.P.O. The feature is called the Olivarez Blue Festoon #14. (A festoon appears to bridge two belts across a zone.)

"Although they appear to project from the [North Equatorial Belt's] south edge,"

Though it was pale pink, Jupiter's Red Spot could be seen as a full ellipse for the first time in seven years. Note the festoon streaks across the Equatorial Zone and the "Blue Spot Sources" in the North Equatorial Belt, from which the festoons emanate. Photo by Jean Dragesco.

This extended sketch of Jupiter on August 7/8, 1986, shows numerous cloud features. Notice the fragmented appearance of the South Temperate Belt and the three White Oval Spots: BC, DE, and FA. A number of blue festoons project from the south edge of the North Equatorial Belt and extend into the Equatorial Zone. The Red Spot is indicated by RS. This sketch was made by I. Miyazaki, who used an 8-inch reflector.



explains Olivarez, "the blue festoons are not part of the NEB itself but project from 'blue spot sources' that lie at the latitudes of the south edge of the NEB." These blue spot sources were discovered by Olivarez in 1983 and are difficult to observe.

There were a number of other highlights during Jupiter's 1986 apparition. The White Oval Spots, discovered in the South Temperate Belt over forty-five years ago, continue to be observed and are, in fact, the second longest-lived features on the planet. (The longest-lived feature, the Great Red Spot, was first observed telescopically in 1831, though it may have been seen by Cassini in 1660.) According to predictions, these spots were supposed to shrink and vanish by 1985; however, they can still be discerned in medium-sized telescopes on nights of good seeing. The largest spots are designated BC, DE, and FA. BC and DE are fairly near each other and can often be seen on the same side of the planet. FA is the smallest and the hardest to see.

"Despite their long life," says Olivarez, "the remaining days of these features are numbered. FA may well disappear in another year or two."

Olivarez also reports that many new small white spots were discovered in the South Temperate Zone in 1986. On August 7/8, I. Miyazaki recorded seven new spots.

Many observers noticed the abnormal width of the South Temperate Belt, a state that has existed since 1984, says Olivarez. Normally this belt is a mirror image of the North Temperate Belt. However, for the past two years it has tended to be broad and, at some longitudes, faint. The North Temperate Belt, meanwhile, exhibited a number of "barges" or "dark rods," cigar-shaped features that may be openings in Jupiter's clouds.

This year Jupiter will come to opposition on October 18 in eastern Pisces. Its diameter will be slightly greater than it was

in 1986, and Jupiter will be positioned significantly higher in the sky for observers in the Northern Hemisphere. This will be a prime opportunity for those with small- to medium-sized telescopes to take in the windswept cloudscape of Jupiter's atmosphere and to look for changes or, perhaps, new features.

Uranus and Neptune

Though few amateurs noticed, Uranus and Neptune came to opposition respectively on June 11 and June 26. Situated in the southern reaches of Ophiuchus, Uranus' featureless green disk could easily be seen in a 6-inch telescope, though its apparent equatorial diameter was slightly less than 4".

More distant Neptune, southeast of μ Sagittari, was little more than a 2.29" bluish-green disk. Considering their almost starlike sizes, these two planets did not offer much to the casual observer with a small telescope. But they were worth a look if for no other reason than to say that you've seen them.

If you didn't get a chance to see the planets last summer, don't miss them this year. In fact, you might begin by observing Saturn now and watching its disk and rings grow in apparent size until opposition in June. And in early October 1988, you can look forward to the best apparition of Mars since 1971, because the planet will be closer to Earth and in a favorable location near the celestial equator. All in all, this is an excellent time to begin observing planets full time. *Jeff Kanipe*

Contributing Observations

Perhaps no other pursuit affords the nonprofessional more opportunity to contribute to astronomy than observing the planets. Most large observatories no longer turn their telescopes and cameras on the planets specifically to monitor them for possible changes or events. Such phenomena are unpredictable and tele-

scope time is too valuable to spend an evening scouring a planet for unusual clouds or brightenings of surface features that might just as likely not appear. For this reason, professional astronomers prefer to leave much of the night-to-night planet observing to amateurs, who are not only more ubiquitous but have also proven to be quite professional in their standard of observations.

Those who wish to contribute their observations to planetary science may do so by sending reports, sketches, and photographs to the appropriate planet recorder for the Association of Lunar and Planetary Observers. Be sure to include the Universal Time of your observations, type of instrument used, and seeing conditions.

Saturn Section

Julius L. Benton, Jr.
Associates in Astronomy
305 Surrey Road
Savannah, GA 31410

Mars Section

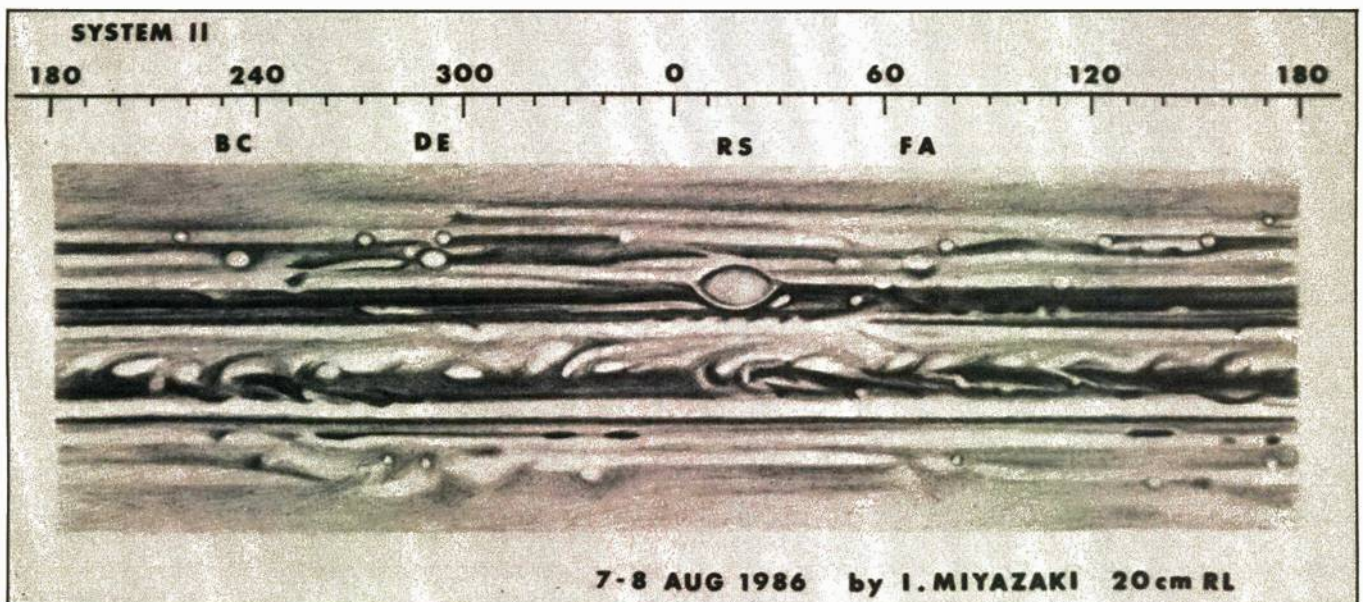
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Wichita, KS 67202



ASTRONOMY

Reviews

The Planets

Byron Preiss, ed.

336 pages, cloth, \$24.95

Bantam Books (1985)

For all their vaunted close relationship, science and science fiction don't coexist very well. Nor should this be surprising, for at bottom they are antithetical: science progresses by ruling out possibilities, science fiction by proliferating them. Science is essentially predictive, whereas science fiction (more properly "SF", which can stretch to cover speculative fiction, a genre with looser rules) tends to bristle whenever its prognostications are put to the test.

The Planets is a curious book. In it a scientist presents an up-to-date factual view of one of the Sun's planets which is followed by a science fictioner's view of what life might be like on that planet sometime in the future. Dividing each section of the book are paintings showing both real and fictional scenes.

While I approached the book with strong misgivings, thinking the technique sounded rather like a shotgun marriage, overall the technique works. The fiction usually hews close to reality and adds what many people consider a necessary human dimension to the science.

On the other hand, I could have done without the illustrations, though individually most are very good. I started by admiring them — they're wonderful "photographs" that no one has yet gotten around to taking — but then I began to resent the way they channeled my imagination. (To put this comment into perspective, however, bear in mind I also react much the same way to the movie version of a book.)

The order of the sections struck me as odd: we begin with Earth and the Moon, and go to Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. So far, so good. But then it's back to Mercury and Venus, and we finish with a last, long hop out to the asteroids and comets. Why? I can only guess the editor felt he'd lose the reader's

interest if he didn't start with tactile reality at the outset.

The choice of authors is good on both sides of the S/SF fence. Among the scientists are William Hartmann (writing on asteroids and comets), Clark Chapman (Mercury), Dale Cruikshank (Uranus and Neptune), David Morrison (Saturn), Joseph Veverka (Jupiter), Michael Carr (Mars), and G. Jeffrey Taylor (the Moon). And the SF side features heavyweights too: Harry Harrison (Earth), Roger Zelazny (Saturn), Philip Jose Farmer (Uranus), Gregory Benford (Jupiter), Frank Herbert (Mercury), Robert Silverberg (Pluto), and Ray Bradbury (Mars). Isaac Asimov and Arthur Clarke contribute paired prefaces.

The science is solid and up to date, with surveys that are admirably concise. (I felt sorry for Cruikshank, though, having to write about Uranus before the Voyager flyby. Nonetheless, he gets through it by largely talking about what Voyager intended to look for.) On the other hand, in the fiction I found a certain sameness to the stories, where plots often hinge on exploration for exploitation.

Will our only experience of these worlds be in these terms? Even if we grant that the initial years (or decades) of human settlement will be brutally difficult and dangerous, why did so many authors limit their visions to just these times? Granting that the stress of "life on the frontier" brings out the best and worst in human character, planetary settlement is also an abnormal existence for humanity as a whole. I would have enjoyed seeing a few more stories told within the framework of a well-settled society rather than within raw pioneer stages.

Who's the book for? That's hard to say. It's not the book to get if you want a summary of current information on the solar system — there aren't enough facts here for the money. On the other hand, anyone interested in SF who's curious about what some big-name authors could do with the solar system certainly gets his wish. It would also be ideal to catch the interest of that fourteen-year-old nephew

of yours who's so deeply into alternative realities that he's lost sight of the one just overhead. All in all, it's a worthwhile and enjoyable book. *Robert Burnham.*

In Advance of the Landing: Folk Concepts of Outer Space

Douglas Curran

132 pages, paper, no price given
Abbeville Press (1985)

If you only frequent the astronomy sections of bookshops, you probably missed this book when it first appeared. Because of its cover, which shows a small concrete ovoid sitting in a field of dry brown grass with a halo of green light hovering over it, most bookstores would put the book in the art or anthropology sections, certainly not among the astronomy books. Let me tell you, you missed a real gem — but hear me out before you dash off to buy it.

I have extraordinarily mixed feelings about this book. In the foreword, Tom Wolfe (of *The Right Stuff* fame) notes that the author has been almost anthropological in the way he's recorded what ordinary people think about life in outer space. Curran, a professional photographer, also has a good ear for the telling phrase, and I have no doubt that the portraits he gives of these people and their obsessions, in both photos and words, are accurate.

The net result, however, is the most amazing — and depressing — collection of crazies I've ever encountered between the covers of a single book. Wolfe compares Curran to social historian Henry Mayhew and to documentary photographers Lewis Hine and August Sander. I think a comparison to Diane Arbus comes far closer to the mark, because no one else has captured the sad grotesqueries common to outcast subcultures as well as she has.

And these people are outcasts. What else can you think of when you read about George Adamski's visits by Venusians and

his rides aboard their saucer-craft? After a brief period of fame — notoriety? — in the 1950s, Adamski faded from view, muttering about persecution and claiming (falsely) that the FBI endorsed his statements. Still convinced that he was a "contactee," Adamski died in 1965, having established a small band of disciples (the only word that fits) to carry on his name.

Then there's the Aetherius Society. Members dress in long robes, raise their right hands, and step up to touch a device mounted on a large photo tripod to "charge a Spiritual Battery." Curran notes that his first meeting with the Society was interrupted by a man who announced the forthcoming arrival of His Eminence, Prince George King de Santorini, Count de Florina. His Eminence, apparently, had just finished up Phase 4 of the Saturn Mission at Lake Powell, Utah.

The Unarius Education Foundation of El Cajon, California, is preparing Earth for the arrival of spaceships from the galactic Confederation. In the Foundation's headquarters is a model of Ernest L. Norman, the late husband of Unarius' founder Ruth Norman. Mr. Norman is shown in his present job as Moderator of the Universe. Unarius also sponsors Conclaves of Light, where members dress in the costumes they wore in past lives on other planets.

I could say more, but a sneaky question

just occurred to me: why do the aliens described by contactees all stand about five feet high and have large, generally bald heads and green or gray skin? Every one of these beings looks like it was abducted from Hollywood's prop rooms sometime in the 1950s. Do all aliens really look like this — or are their makers' imaginations stuck somewhere back in Ike's first term? And can we look forward to a new iconography of aliens when the kids raised on Spielberg and Lucas (not to mention the nasties in *Aliens*) grow up?

Not all the rockets and flying saucers Curran shows are the work of lunatics. Some are simply advertising gimmicks. Countless space-theme restaurants, gas stations, and motels dot the countryside; many of them are in the Southwest where space research brought lots of people and money in the late 1940s and early 1950s. (The other day I passed the defunct-looking Nike Bar in Carrizozo, New Mexico, a small crossroads town north of White Sands Missile Range. The bar's sign, fully twenty feet high and easily thirty years old, shows a stylized Nike missile roaring off the pad.) These artifacts simply capitalize on an eye-catching object and promulgate no new cosmic awareness.

Reading this book will provoke you to incredible gales of laughter or send you on a downer that'll last for days. As you move from page to page you ping-pong

between hilarity and pathos. A lot of ingenuity has gone into a couple of these fantasies but most, unfortunately, are simply shabby and down-at-heel. In every case, however, the people look like thoroughly nice folks. I didn't detect a single con-artist — in fact, these people would be easier to take if they weren't so sincerely deluded.

Perhaps it's a mistake to feel sorry for them. After all, many show every hallmark of a healthy ego and are probably bedrock-convinced that they're right, and that the rest of us are the loonies because we don't grasp the cosmic truth. But, after a generation of real space travel, it's depressing that the cosmic confederacies inside these people's minds glow brighter than what's really out there. *Robert Burnham.*

Interdisciplinary Approaches to Astronomy

Andrew Fraknoi, et al.

32 pages, paper, \$3

Astronomical Society of the Pacific (1986)

Interdisciplinary Approaches provides listings of books and records containing music and poetry with astronomical themes. Included is a bibliography listing magazine articles pertaining to poetry and music in astronomy.

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Jane's Spaceflight Directory — 1986
Reginald Turnill, ed.
453 pages, cloth, no price given
Jane's Publishing Company, Ltd. (1986)

Jane's annual reference spaceflight directory, first published in 1984, provides up-to-date information on the history and progress of world spaceflight and space programs.

**Atlas of Historical Eclipse Maps:
East Asia 1500 BC–AD 1900**
F. R. Stephenson and M. A. Houlden
431 pages, cloth, \$79.50
Cambridge University Press (1986)

Providing solar eclipse track maps covering East Asia for the past 3,000 years, this oversized atlas also gives the dates and times of eclipses, longitude and latitude limits, and percentages of obscuration.

Cosmological Constants
Jeremy Bernstein and
Gerald Feinberg, eds.
328 pages, cloth, \$38
Columbia University Press (1986)

Without a doubt, cosmology has come a long way in the past sixty-five years, and

the direction and progress of cosmological research is especially evident in *Cosmological Constants*, a collection of "landmark" papers in the field of cosmology written from 1917 to 1982. Among the papers included are "Cosmological Considerations on the General Theory of Relativity" by Albert Einstein, "Interpretations of the Red Shift" by Georges Lemaitre, "A Measurement of Excess Antenna Temperature at 4080 Mc/s" by Arno Penzias and Robert W. Wilson, "Cosmological Production of Baryons" by Steven Weinberg, and "Inflationary Universe: A Possible Solution to the Horizon and Flatness Problem" by Alan H. Guth.

**Fundamental Astronomy and
Solar System Dynamics**
R.L. Duncombe, J.H. Lieske, and
P.K. Seidelmann, eds.
348 pages, cloth, no price given
D. Reidel (1986)

Reprinted from *Celestial Mechanics*, this book is a collection of papers honoring Professor Walter Fricke on his seventieth birthday. Notable papers included are "Prospects for Astrometry with the Hubble Space Telescope" by W. H. Jeffreys, et al., "A Review of Astrometric Observing" by Robert S. Harrington, and "Coordination

of Minor Planet Orbital Studies, Past, Present, and Future" by Brian G. Marsden.

Physics of the Sun
Volume II: The Solar Atmosphere
P. A. Sturrock, T. E. Holzer,
D. M. Mihalas, and R. K. Ulrich, eds.
385 pages, cloth, \$62
D. Reidel (1986)

This volume contains monographs addressing various aspects of solar research, particularly work pertaining to the Sun's atmosphere, its spectral analyses, the determination of the Sun's atmospheric properties by its radiational output, solar flares, and observations and mechanisms of solar nuclear processes.

The Quest for SS 433
David H. Clark
206 pages, paper, \$6.95
Penguin (1986)

Subtitled "The Celestial Detective Story That Changed Our Understanding of the Universe," this book was written by the chair of the Space Astrophysics Group at Rutherford Appleton Laboratory. It is an account of the discovery and latest research on the mysterious stellar object in Aquila.

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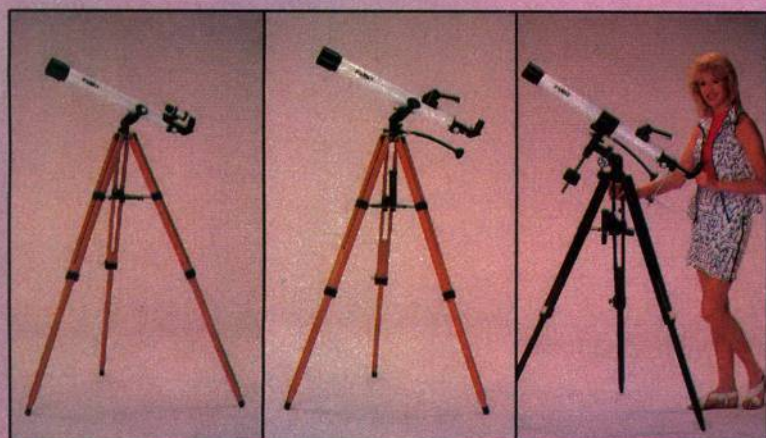
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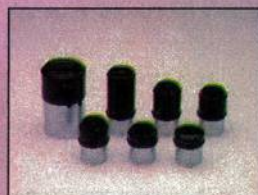


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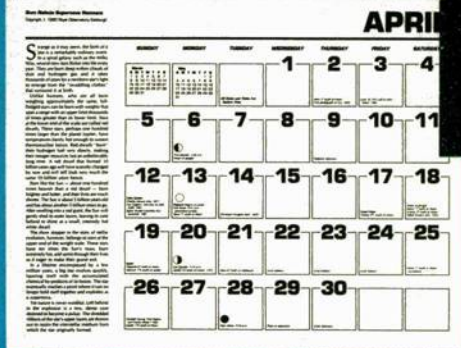
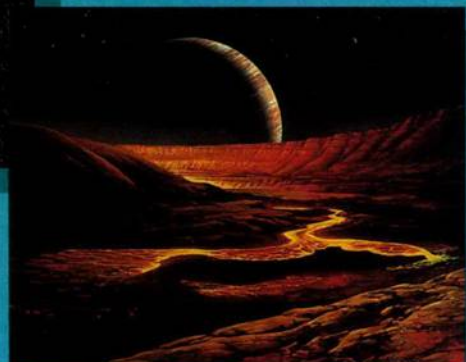


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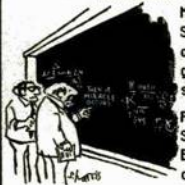
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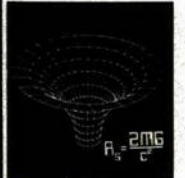
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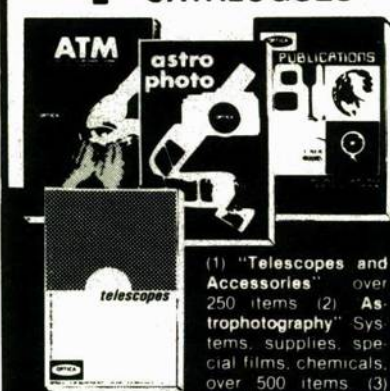
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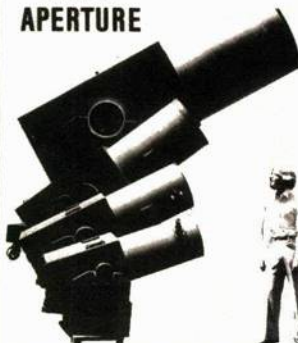
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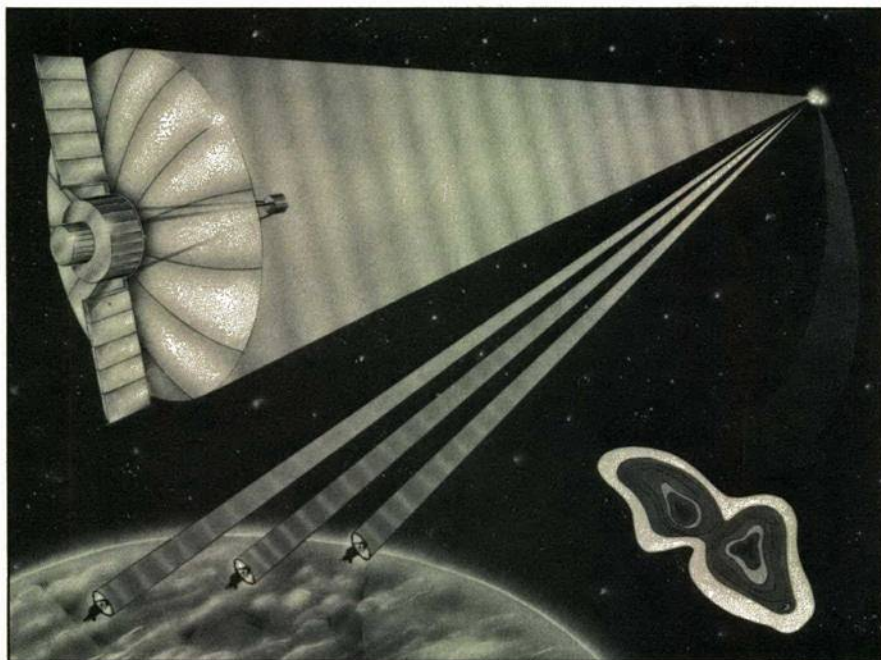
New Satellite Would Extend VLBI into Space

Last summer's successful test of a technique for making radio observations from space has given impetus to a proposed orbiting radio telescope. This telescope would observe radio sources simultaneously with radio telescopes on the ground.

Using the 4.8-meter (16-foot) antenna of NASA's Tracking and Data Relay Satellite (TDRS) and two 64-meter (210-foot) ground-based radio telescopes, a team of scientists, led by researchers at the Jet Propulsion Laboratory, obtained resolutions of three quasars, superior to those possible using ground-based radio telescopes. The observations, conducted in July and August 1986, were of the quasars designated PKS 1730-130, PKS 1741-038, and PKS 1510-089.

The experiment extended into space for the first time a technique known as very long baseline interferometry (VLBI). For the past twenty years Earth-based VLBI has proved to be an effective method for increasing the resolution of radio telescopes. Radio signals received by two or more antennas are blended to achieve resolution of a radio source much greater than that obtained by a single radio telescope. The greater the distance separating the receivers, the greater the resolution. The resolution of the TDRS and Earth-based radio telescopes was equivalent to that obtained by an antenna 1.4 times the diameter of Earth.

The success of the TDRS experiment proved that with a properly designed radio antenna in orbit, the range and resolution of radio astronomy could be significantly extended. Such an antenna is being proposed by scientists from NASA and the European Space Agency. Called QUASAT, the satellite would be an orbiting 15-meter (49-foot) diameter antenna that would make interferometric observations in concert with other ground-based radio telescopes. Depending on the altitude of its orbit, QUASAT would be



Radio observations made in space by the proposed QUASAT satellite would be combined with the signals of Earth-based radio telescopes to achieve better resolution of quasars and distant galaxies. NASA/JPL illustration.

capable of angular resolution between 0.000075 and 0.000025 arcseconds.

Frank Jordan, deputy division manager of the Systems Division at JPL, said QUASAT would be kept busy studying the nuclei of quasars and active galaxies, improving methods for determining the scale of the universe by trigonometric measurements of distant galaxies, and studying stellar radio sources such as x-ray binaries. QUASAT would also examine interstellar scattering of starlight, star formation, interstellar masers, active stars, and supernovae.

The mission lifetime of QUASAT would be between two and five years. Its cost is estimated at about \$200 million. The QUASAT proposal is presently at NASA headquarters in Washington, D.C., awaiting official approval.

8-Meter Telescope Planned for Southern Hemisphere

The early 1990s will see a new 8-meter optical telescope built in the Southern Hemisphere. The agreement to design and build the instrument was reached in October 1986 by the Carnegie Institution of Washington, the University of Arizona, and Johns Hopkins University. It will be built at the site of the Carnegie Institution's Las Campanas Observatory in the Chilean Andes.

The three institutions will jointly fund and operate the new facility, which is expected to cost \$25 million. Observing time on the telescope will be divided between the three partners according to their financial commitments: Carnegie Institution, 50 percent; University of

Arizona, 25 percent; and Johns Hopkins, 25 percent. Membership in the observatory's managing body will also reflect this division.

The mirror for the 8-meter telescope will be constructed by the University of Arizona using the new "spin-cast" technology developed by J. Roger Angel. The process, in which a glass blank is spun in a rotating furnace, produces a parabolic curve in the mirror that requires little traditional grinding and polishing. The resulting mirror also has a very short focal ratio.

The development of increasingly powerful ground-based telescopes, like the 8-meter, is viewed as an essential counterpart to new Earth-orbiting telescopes. According to Arthur F. Davidsen, director of the Center for Astrophysical Sciences at Johns Hopkins, "The 8-meter telescope will give Hopkins astrophysicists another major tool for the study of the universe, one which will significantly complement what we hope to be able to do with the Hubble Space Telescope." Ground-based telescopes are also needed to plan and follow up on observations made in orbit.

The 8-meter telescope project was initiated by the Carnegie Institution in May 1985. To devote more of its resources to this project, the Institution moth-balled the 100-inch Hooker reflector at its Mount Wilson Observatory in Pasadena, California. It is now seeking other operators for the observatory.

U.S. to Collaborate with Japan on Solar Flare Experiment

The United States has chosen the research team to work with Japan in the design and operation of a soft x-ray telescope that will be placed aboard Japan's solar observation satellite, SOLAR-A, to study high energy phenomena on the Sun.

Dr. Loren W. Acton of the Lockheed Palo Alto Research Laboratory in California, who was a payload specialist on NASA's Spacelab-2 Shuttle mission in 1985, will head the U.S. research team in the development of a soft x-ray telescope, which will provide images of the relatively cool pre- and post-flash phases of solar flares. The U.S. team is also responsible for supplying the optics and detector for the telescope, while the Japanese will provide the supporting electronics, power supply, and data control system.

The Japanese will also develop a hard x-ray telescope that will reveal the hottest (greater than 30 million Kelvins) kernel of flares. Because hard x-rays are more energetic than soft x-rays, hard x-rays indicate activity at higher temperatures.

The use of both telescopes will allow second-by-second image analysis of solar flares as they grow and die. U.S. researchers will assist the Japanese team in prelaunch preparations and launch and mission operations; the U.S. team will also

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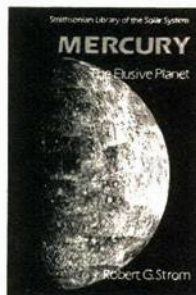
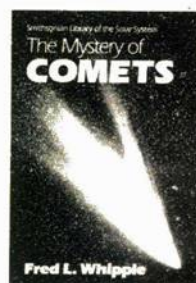
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have a leading role in the analysis of data received from the experiment.

The Japanese satellite is scheduled for launch from the Kagoshima Space Center in Japan during the August/September 1991 launch window.

Density Determines Destiny of the Universe

When they are not wrestling with the various theories on how the universe began, cosmologists grapple with its ultimate fate: will it expand forever, thinning itself like a distending puff of smoke, or eventually collapse into a super-dense state and perhaps start the whole process again?

The pivotal factor in this question is the mean density of the universe, a value determined by the amount of mass occupying each cubic centimeter of space. Too little density and the universe expands forever; too much density and the universe collapses.

In an article in the August 1, 1986, *Astrophysical Journal*, astronomers Edwin Loh and Earl Spiller of Princeton University presented new observational evidence indicating that the average density of the universe lies near or at the "critical density" necessary to produce an exact balance between cosmological expansion and gravitational attraction.

Up until now, most calculations that derived a value for the mean density of the universe favored an unbound or "open" universe. Previous values have been obtained by counting the number of galaxies in selected volumes of space, adding their masses, and dividing the total by the volume of space. However, many cosmologists, including Loh and Spiller, believe such measurements have not been complete enough to determine whether the universe is open or closed.

Essentially, Loh and Spiller's analysis sought to fill this gap by obtaining the redshifts of one thousand galaxies and thus providing the sufficient numbers needed to derive an accurate mass density of the universe. To do this, five areas of sky were surveyed, each measuring 7 by 10 arcminutes. Each field contained about two hundred galaxies. Loh and Spiller state that their survey is equivalent to measuring the volume of a cone extending thousands of megaparsecs into space. The geometry of space and whether the universe is open or closed can then be inferred by the rate at which the volume of the cone increases at large distances.

According to their data, the density of the universe lies between 0.6 and 1.2 times the critical density, with a mean value of 0.9. This is consistent with a density value of 1, which would mean the universe is critically bound, or "flat." Since their technique measures the shape of space-time, it is not sensitive to whether the mass is visible or not. The work therefore implies that there is roughly one

hundred times more dark matter in the universe than we can see as stars and galaxies. These results are in line with the Einstein-de Sitter model of the universe, which assumes a uniform, homogeneous expanding or contracting universe, where gravity is the only force that needs to be considered.

Meteorites Escape from Mars

Because of their geochemical composition, three classes of stony meteorites — shergottites, nakhlites, and Chassigny — seem most likely to come from Mars. And now two researchers from the California Institute of Technology have determined how these meteorites got to Earth.

The meteorites are unique because of the relative abundance of certain chemical compounds, not found in other meteorites, the Earth, or Venus. In addition, they appear to come from a planet with substantial gravity. And, because their composition is close to that of the Martian atmosphere, as measured by Viking, these meteorites are believed to result from impact on Mars.

According to John D. O'Keefe and Thomas A. Ahrens of the California Institute of Technology, reporting in the October 17, 1986, issue of *Science*, the high-speed vapor jets resulting from the collision of a meteorite with Mars could carry planetary samples at a rate fast enough to escape from Mars' gravity.

This mechanism also explains how the samples got to Earth in a lightly- to moderately-shocked state. If a meteorite bombarded Mars and chipped off pieces, the resulting chips would have been melted or vaporized by the impact. The jet mechanism, however, both moves the chips at rates fast enough to escape the gravity of Mars and allows them to reach Earth in relatively good condition.

Interferometer Measures Angular Diameter of Sirius

The only star that exhibits a clear-cut disk in ordinary telescopes is the Sun. But even in the largest telescopes all the stars in our region of the Milky Way are too distant to be seen as anything but points of light, even though their true diameters may be greater than the Sun.

In recent years astronomers have made great strides toward resolving the disks of nearby stars with a technique called stellar interferometry. Classic stellar interferometry involves receiving a star's light simultaneously at two different receiving points and then combining the light or photoelectric signal to compare the "phase" of the light waves, i.e., the relative distance between the crests and troughs of the two light waves. The difference in phase depends on the size of the source (the star) and the distance

separating the receivers. From this difference a star's angular diameter can be derived, providing the star has a large true diameter and the elements of the interferometer are separated by a great enough distance.

Two types of stellar interferometry are practiced today. Intensity interferometry measures the total power (radiant intensity) emitted by a star and compares it to the separation distance of the two telescopes. Such an interferometer was built in Narrabri, Australia, and measured the angular diameters of all the stars it had the power to measure before it was dismantled.

As reported in the September 18, 1986, issue of *Nature*, John Davis and William J. Tango of the Chatterton Astronomy Department of the University of Sydney in Australia have used a relatively new technique called amplitude interferometry to measure the angular diameter of the bright star Sirius. This method, which has never been used on main sequence stars, compares the amplitudes of the incoming light waves.

The amplitude interferometer employed to make these new measurements of Sirius' angular diameter consists of two 6-inch diameter, flat mirrors that direct starlight to a fixed, central optical system. The mirrors have a "baseline," or separation distance, of 37 feet. The central optical system utilizes "active" mirrors to counter the image distortion caused by atmospheric turbulence. It is also designed to delay one of the light beams until interference fringes, caused by the interacting light waves, are seen.

According to the new measurements, Sirius has an apparent diameter of 0.00563 arcseconds, a value that concurs with the Narrabri measurement of 0.00560 arcseconds. According to Davis and Tango, the success of this method "clearly demonstrates that accurate determinations of angular diameters are possible with a small-aperture amplitude interferometer through the turbulent atmosphere."

Quasars Faster than the Speed of Light?

According to Einstein's special theory of relativity, matter cannot travel faster than the speed of light. So how are astrophysicists explaining the recent discovery of seven more quasars that appear to be ejecting blobs of material moving faster than the speed of light? As an optical illusion.

This discovery by an international team of astronomers from the California Institute of Technology; the Max Planck Institute for Radio Astronomy in Bonn, West Germany; and the Naval Research Laboratory in Washington, D.C., brings the number of these "superluminal" quasars to fourteen and changes their status from rare to common.

How to start out right in astronomy

Use new NIGHTVISION™ 9x63 Giant Binoculars and enjoy these 10 exciting observing activities

Let's face it. Telescope manufacturers would like you to believe that the only way to start out in astronomy is to buy their expensive telescopes. Nothing could be further from the truth!

You can enjoy over 27 activities with new, lightweight NIGHTVISION 9x63 Giant Binoculars. Each one is fascinating and totally engrossing. Some even have special associations and clubs devoted to them. In fact, you enjoy the best of astronomy with new NIGHTVISION 963s. At a fraction of the cost of a telescope. And without the hassle of moving and setting up 40 to 50 lbs of heavy equipment. Consider this:

In one night with your NIGHTVISION 963 Giant Binocular, watch variable stars slowly pulse on and off like cosmic beacons, trace the path of an asteroid as it drifts through space, rediscover Saturn's giant satellite, follow the orbit of Jupiter's moons—the ones Galileo discovered, and maybe even spot a super-nova in a far off galaxy. All this, plus great fun, lots of thrills and the time of your life, too!

Here are 7 more of the most exciting observing activities you can begin immediately with your NIGHTVISION 963s. And at the same time, become a real expert on the night sky—to the envy of your friends!

1. The NIGHTVISION 963s have the widest field of view of all giant binoculars. Scanning the the Milky Way star clouds is an exhilarating experience you'll just never forget. Giant nebulae such as the Veil and North American Nebulae fit easily in the view. And the Pleiades open cluster, a stunning group of bluish white stars set in dusty nebulosity, makes a grand sight sure to wake up even the most hum-drum observer.

2. M1, the Crab Nebula in Taurus, is the result of a super-nova explosion first seen by ancient Chinese astronomers in 1054. See it clearly through your NIGHTVISION 963s as a delicate cloud floating through space. You can see 52 other nebulae with your NIGHTVISION 963 Giant Binocular simply because it gathers more light—2½ times more than popular, daytime 8x40 binoculars. In fact, each of the NIGHTVISION 963's two 63mm objective lenses is larger than most amateurs' first telescopes!

3. Every optical surface of your NIGHTVISION 963 is magnesium fluoride hard coated—every objective lens, every prism, and every eyepiece lens—for extremely high contrast and brightness. This means you easily see plenty of detail and structure in galaxies. Dust lanes and spiral arms of galaxies such as M33 in Triangulum just make an awesome sight.

4. For an engrossing and challenging pastime, try your hand at asteroid tracking. Some astronomers are so taken in by these chunks of rock, they track hundreds yearly. It's easy and fun with the NIGHTVISION 963—even from the city. Their rugged, lightweight aluminum construction means you can hold them for hours without tiring—extremely important for the most fun. Amazingly, the new NIGHTVISION 963 weighs almost 3 lbs less than any other giant binocular. The advanced Dach roof prisms make this compact design possible.

5. The NIGHTVISION 963 focuses surely and positively. Stars snap into and stay in focus. A necessity when viewing close double stars such as Albireo, in the constellation Cygnus. Just mention you're actually seeing two stars that orbit each other, one topaz yellow, the other sapphire blue, and your friends will promptly snatch your NIGHTVISION 963s from you!

6. Watch sunrise creep across the Moon through your NIGHTVISION 963s. With 9 times magnification, large craters and mountain ranges stand out in bold relief against the long, early-morning shadows. And 9 times magnification means you can hand-hold your NIGHTVISION 963 for steady, relaxed viewing.

7. There are thousands of variable stars to keep an eye on with your NIGHTVISION 963s. Some, like Mu Cephei, flicker and fade for no rhyme or reason. The real fun is estimating their current brightness against the surrounding stars. With your NIGHTVISION 963, enjoy fatigue free viewing with no headaches—even after intense concentration. Because the new NIGHTVISION 963 is extremely accurately made. Its optics are precisely aligned. The optical tubes are exactly parallel. And their magnifications exactly equal.

And take your NIGHTVISION 963 Giant Binocular with you for double the fun and excitement on your vacation. Discover new night time delights you've never seen before. At just 1260 grams, the NIGHTVISION 963 is the smallest and lightest giant binocular available and will fit anywhere.

NIGHTVISION 963s are coated in matte black rubber for the sleek, sophisticated European look. And to protect them from dirt, moisture, nicks and scuffs, without looking the worse for wear. NIGHTVISION 963s come complete with diopter adjustment, roll down rubber eye-cups for comfortable glare-free viewing, a fully adjustable neckstrap, a durable carrying case, and a lifetime warranty against manufacturing defects and workmanship.

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And to make sure you start out right and enjoy your NIGHTVISION 963s the most, we'll also send you, as a FREE gift, the Audubon Field Guide to the Stars and Planets. This pocket-sized gem is filled with tables of the best double stars, galaxies, variable stars, clusters, asteroids, etc., the complete Sky Atlas 2000 in 52 charts, 72 monthly Sky Maps and 8 more of the Moon.

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Signals received by radio telescopes distributed from California to central Europe allowed astronomers to draw charts of the detailed structure of quasars and to compare them over time. But the charts showed that the blobs were moving up to seven or eight times the speed of light.

The apparent contradiction to Einstein's theory is explained by . . . Einstein's theory. If the objects are moving toward Earth at *almost* the speed of light, then a difference in the perception of time occurs. Because light emitted later travels a shorter distance, terrestrial observers see the motion occur in less time than actually elapses at the object. So the speed of light — from the reference point of the blob — has not been surpassed.

This explanation means, however, that only motion directed toward Earth can result in superluminal expansion; if the motion is at right angles to Earth, the phenomena should not occur.

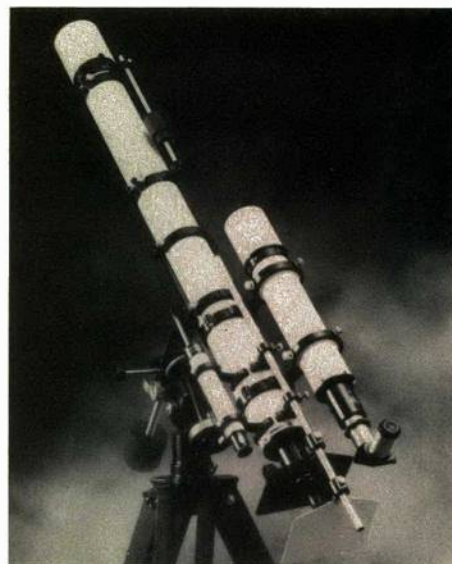
However, because the ejection of matter at speeds close to the speed of light is now considered a common phenomenon, the objects can be studied as a well-defined group instead of as a rare class of

randomly-selected objects. The study of known superluminals (six more are candidates) may show that a significant number of these objects are pointed toward us. If this conclusion can't be reached, alternative explanations of the phenomena will need to be explored.

The seven new superluminal objects could also offer new insights into the central engines that generate the enormous power of active galactic nuclei and quasars. Scientists believe the power is generated by a spinning supermassive black hole at the center of an accretion disk.

As material falls toward the black hole under the influence of its gravitational field, the material is ripped apart and falls into the disk, eventually streaming into the black hole. The gravitational potential energy the material loses as it falls into the black hole is believed to be the energy source of the central engine.

But some of this energy could be converted into a jet of material moving outward along the spin axis of the black hole, and the material would need to be traveling at close to the speed of light to escape the black hole's gravitational field.



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January 29-February 1

3rd Annual Winter Star Party

(sponsored by the Southern Cross Astronomical Society), Everglades National Park, Florida. Contact: Tippy D'Auria, 1051 N.W. 145 St., Miami, FL 33168. Phone: (305) 685-6001.

February 4-March 15

"25 Years of Space Photography"

(140 photographs taken by unmanned spacecraft; exhibit organized by the Baxter Art Gallery at the California Institute of Technology and sponsored by IBM), Exploratorium, San Francisco, California. Contact: Joe Ansel, 3610 Lyon Street, San Francisco, CA 94123. Phone: (415) 563-7337.

February 12-14

Automatic Photoelectric Telescopes II

(Fairborn IAPPP Symposium), Apache Junction, Arizona. Contact: Russell M. Genet, Fairborn Observatory, 1357 N. 91st Pl., Mesa, AZ 85207.

February 21-22

American Workshop on Cometary

Astronomy (sponsored by the International Halley Watch), Jet Propulsion Laboratory, Pasadena, California. Contact: Comet Workshop, International Halley Watch, 169-214 Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109.

March 14

Astrophoto VII (symposium on amateur astrophotography, sponsored by Ventura Co. Astronomical Society and Orange Co. Astronomers), Moorpark College,

Moorpark, California, at 8 a.m. Contact: VCAS/Astrophoto VII, P.O. Box 982, Simi Valley, CA 93062.

April 23-25

Middle Atlantic Planetarium Society

(annual meeting), Centerport, New York. Contact: Vanderbilt Planetarium, Little Neck Rd., Centerport, NY 11721.

April 25

Family Astronomy Day (sponsored by the Custer Institute Astronomy Group), Custer Institute, Southold, Long Island, New York. Contact: Warren Hamburger, 2280 South Grand Avenue, Baldwin, NY 11510. Phone: (516) 223-7878.

May 9

14th Annual Astronomy Day. Contact:

Gary E. Tomlinson, Astronomical League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503.

May 21-22

19th Annual Riverside Telescope

Makers Conference (sponsored by the Riverside Astronomical Society and the San Bernardino Valley Astronomers), Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92503. Phone: (714) 689-6893.

AstroCalendar notices must be submitted at least four months in advance of the date of the event.

When contacting organizations that are sponsoring events, enclose a self-addressed, stamped, legal-size envelope for their response.

Sculpting the MOON



Excavated by violent impacts, layered with flows of lava, and softened by a relentless rain of meteorites, the lunar surface displays a geological past over 4 billion years old.

by Michael T. Kitt

A mountain over 10,000 feet high, created not by forces within the planet but by the force of objects crashing down from above.

A circular basin over 900 miles across, filled with lava that flowed over a period of 500 million years.

A riverlike channel half a mile wide and 80 miles long that once flowed with molten rock instead of water.

A layer of fine soil 20 yards deep, produced by meteorites relentlessly crushing the planet's surface.

These surface features of the Moon are the relics of an evolutionary process radically different from Earth's. Long before Earth had any of its present features, the Moon had developed the outward features of its 2,200-mile-diameter sphere. Current terrestrial surface features were created over millions of years: major mountain chains like the Rockies formed 50 million years ago; glaciers have been active in only the last 4 million years. The surface of the Moon we see today, in contrast, was essentially complete over 3 billion years ago.

Only in the last twenty years — since the initiation of the Apollo Program in the 1960s — have scientists been able to put together a clear picture of the processes that sculpted the Moon. The soil and rock samples returned to Earth by Apollo astronauts indicate that the Moon formed at approximately the same time Earth did — 4.6 billion years ago. A thin crust quickly formed on the molten sphere and gradually grew deeper as heavier elements sank toward the core. This chemically-differentiated crust was bombarded by large meteorites or comets that left immense basins on all sides of the Moon and spread debris over most of the surface. As the bombardment tapered off, a long era of volcanism that filled many of the large basins with dark lava followed, forming the maria we now see. Slow but constant erosion by small impacts continues to the present day.

An Uncertain Origin

Although the Apollo Program greatly improved our understanding of the Moon, it did not settle the problem of the Moon's origin. Apollo did, however, supply conclusive evidence of the Moon's age. Radiometric dating of the lunar material has revealed small particles 4.5 billion years old. This corresponds to the age of the Earth and the solar system, so it is clear that the Moon, regardless of how it originated, came into existence 4.6 billion years ago.

The events in the earliest years of the Moon are

sketchy at best, but we can infer much of what happened in those years from our current knowledge of the Moon. The accretion of the Moon from primordial material is believed to have taken less than 100 million years. This rapid convergence of matter falling in on itself would have produced enough heat to melt the outer layer of the Moon, perhaps to a depth of 200 miles.

As accretion ended a thin crust began to form. Half of the crust had formed 4.5 billion years ago, and 200 million years later the entire crust was in place. The process of chemical differentiation began as heavier elements sank beneath the surface. The lunar samples, which were relatively enriched with the heat-producing radioactive elements potassium, uranium, and thorium, provided evidence for differentiation. If the Moon as a whole had the same amount of these elements, it would be entirely molten. Since this is not the case, the crust must be chemically distinct from the rest of the Moon.

The samples gathered by Apollo astronauts from the lunar highlands, the light-colored areas of the Moon that cover more than three-quarters of its surface, were igneous rocks, which are produced when molten rock cools. The chemical composition of these rocks is dominated by the calcium and aluminum silicate mineral called plagioclase. As the molten ocean cooled, light plagioclase crystals tended to float upward and became concentrated in a layer that became the crust.

The Bombardment of the Moon

Perhaps the greatest scientific surprise of the Apollo Program was that the oldest feature on the Moon, the extensively cratered highlands, was composed not of material produced during the accretionary process but was formed more than 400 million years later. Except for minute soil grains in the lunar samples, very little of the original crust was found. Lunar highland rocks have ages between 4.2 and 4.0 billion years; the majority are less than 4.1 billion years old.

The highland rocks provided clues to what became of the missing 300 million years of lunar geological history. These rocks were of a unique type called breccia, a rock formed from the fragments of other rocks. These breccias are spread over the lunar highlands to depths of possibly a mile or more. The violent shattering of the crustal rocks by impacts and subsequent recementing of the pieces produced the breccia. The radiometric clocks of the impacted rocks were reset to the date of the impact

A view from above the Moon's eastern limb shows the major features of the northeastern quadrant of the near side.

CAUCASUS
MOUNTAINS

Apollo 15
Landing Site

MARE
SERENITATIS

TAURUS
MOUNTAINS

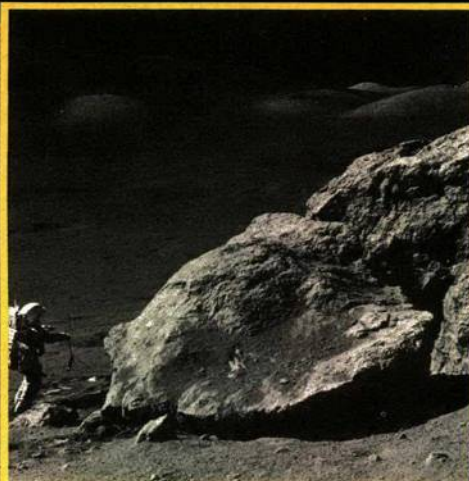
Apollo 17
Landing Site

PROCLUS

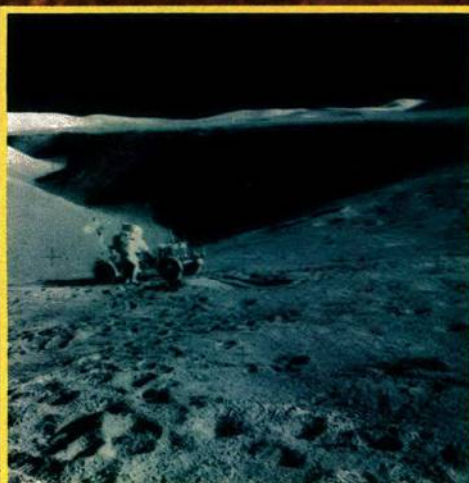
MARE
TRANQUILLITATIS

Apollo 11
Landing Site

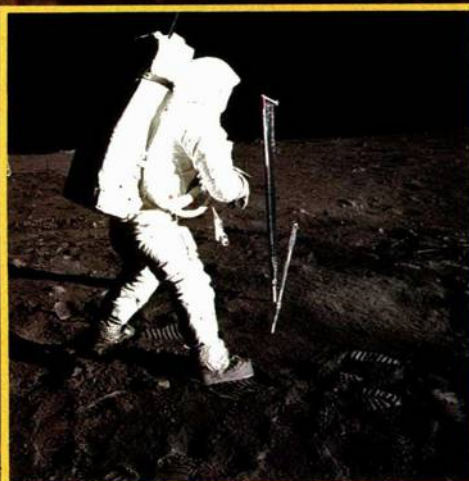
MARE
FECUNDITATIS



A boulder of lunar bedrock that had rolled down a mountain slope was sampled by Apollo 17's Harrison Schmitt.



Hadley Rille, a channel that once flowed with molten rock, was explored during the Apollo 15 mission.



Samples of the finely-ground lunar soil, or regolith, were collected by Edwin Aldrin at the Apollo 11 landing site.

— old rocks were transformed into younger ones.

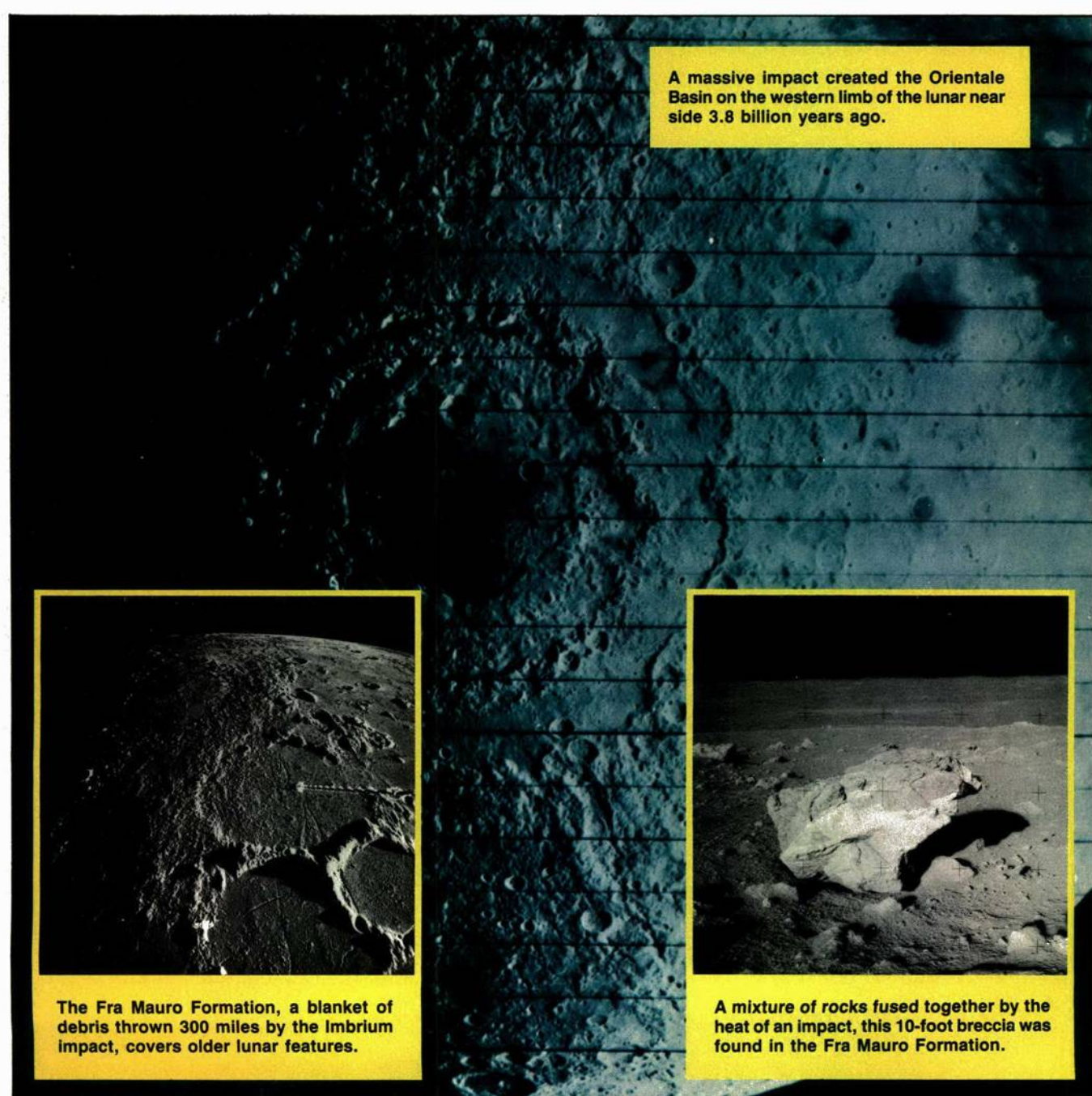
The Moon underwent a 300-million-year period of violent bombardment beginning 4.2 billion years ago. The only plausible cause for the enormous circular basins that dot the lunar surface — Mare Imbrium, Serenitatis, and Nectaris, among others — is the massive impacts of large asteroids or comets. During this period the forty-three major lunar basins were formed and enormous amounts of debris, or ejecta, were thrown over much, if not all of the Moon.

The Imbrium Basin, which is over 900 miles across, was excavated by an asteroid about 60 miles in diameter. A thick blanket of material, now named the Fra Mauro Formation, was tossed over much of the near side of the Moon. This ejecta flowed across the lunar surface and pooled on low-lying crater floors and in the intercrater plains. Huge clots of ejecta scored the immediate vicinity, reducing the ramparts of the adjacent Serenitatis Basin to

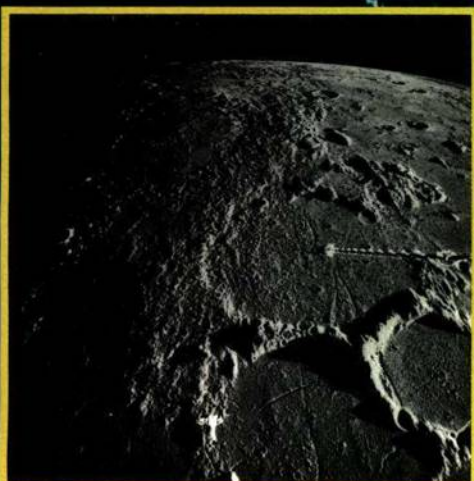
a series of truncated hills known as Montes Haemus. Farther away flying boulders gouged valleys radial to the basin. In a few short hours the face of the Moon was altered drastically. Rocks collected from the Fra Mauro Formation by Apollo 14 astronauts were formed 3.9 billion years ago.

The ages of the basins indicate that this era of bombardment ended suddenly with a flurry of impacts. The oldest basins, such as Mare Tranquillitatis and Mare Nubium, formed not long after the lunar crust solidified. Three major near-side basins — Serenitatis, Crisium, and Imbrium — formed within 100 million years of one another. Mare Orientale, which is partially visible on the western limb of the lunar near side, formed 3.8 billion years ago and is the Moon's youngest basin.

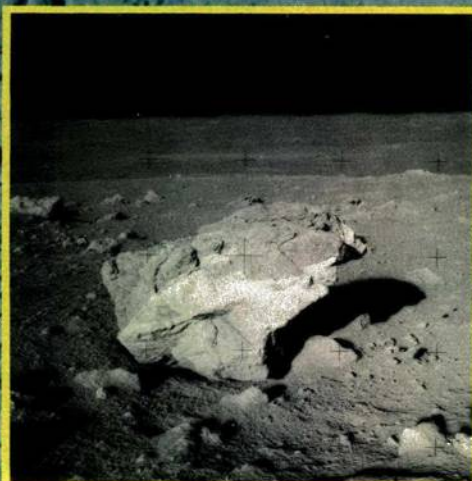
This relatively short, late basin-forming period, known as the "terminal cataclysm," is believed to have been caused by collisions with satellites much smaller than the



A massive impact created the Orientale Basin on the western limb of the lunar near side 3.8 billion years ago.



The Fra Mauro Formation, a blanket of debris thrown 300 miles by the Imbrium impact, covers older lunar features.



A mixture of rocks fused together by the heat of an impact, this 10-foot breccia was found in the Fra Mauro Formation.

Moon, which were also circling the Earth in the early stages of the solar system. The Moon collided with these satellites as it gradually receded from Earth.

The peak of the bombardment occurred between 4.0 and 3.9 billion years ago. Lunar scientists use the Imbrium impact date of 3.9 billion years to mark the end of this era, called the Nectarian Era, and the beginning of the next phase of lunar evolution, called the Imbrian Era. The period of intense bombardment, which eventually tapered off after the first billion years of lunar history, produced the heavy cratering that is seen in the highland areas.

Lava Fills the Impact Basins

By the end of the Nectarian Era the surface of the Moon was covered with impact craters large and small. During the Imbrian Era the low-lying basins were gradually filled with molten rock. This process created the dark maria, the dominant features of the near side of the Moon.

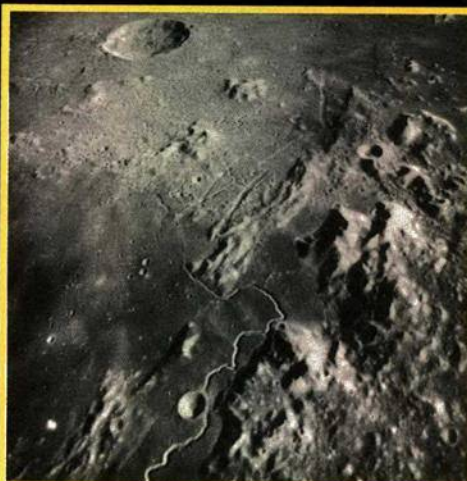
Prior to the space exploration program, astronomers

could not find conclusive evidence for the volcanic origin of the maria. Where, they asked, was the source of this huge amount of lava? Why can't we see the lava flow fronts? Where are the volcanic domes and shield formations that are consistent with the level of activity implied by the great size of the maria?

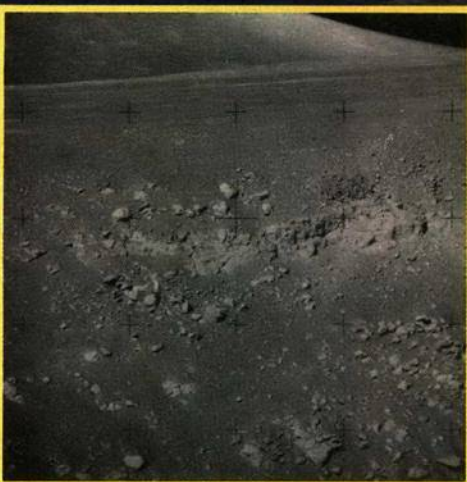
These questions were neatly resolved by a simple experiment performed on some of the first samples of lunar lava brought to Earth. When the lunar basalt samples were melted in the laboratory, they had the consistency of ordinary motor oil. The facts then fell into place.

The maria lava spread in thin sheets for hundreds of miles and were gradually built up by successive eruptions over a period of hundreds of millions of years. These tongue-like flows, clearly photographed from lunar orbit, were much too fluid to create volcanic shield constructs like those on Earth and Mars. The sizes and shapes of crystals in the sampled lava indicate that the lava cooled

Dark lunar lava filled crater Tsiolkovsky to create one of the few maria on the lunar far side.



The riverlike Hadley Rille once carried molten rock from the Apennine Mountains (lower right) into Mare Imbrium.



Successive thin flows of lava produced this outcropping of layered basalts along the rim of Hadley Rille.

within a few years — further evidence that the maria are composed of multiple thin flows. The resulting smoothness of the mare surfaces made the maria an ideal site for the first lunar landing in 1969.

Apollo 15 astronauts photographed individual lava flows in the wall of Hadley Rille, a winding channel running from the Apennine Mountains into Mare Imbrium. The lava flows were each only a few yards thick, but one eruption followed another until a deep layer of basalt filled the mare basins. The Hadley Rille basalts were laid down 3.3 to 3.2 billion years ago.

The lava that formed the maria was produced by another period of melting 60 to 150 miles below the lunar surface. Concentrations of the radioactive elements uranium, potassium, and thorium produced pockets of melted rock that flowed to the surface through the regions of fractured rock associated with the basins.

The lava-producing zone gradually moved deeper; 3.2

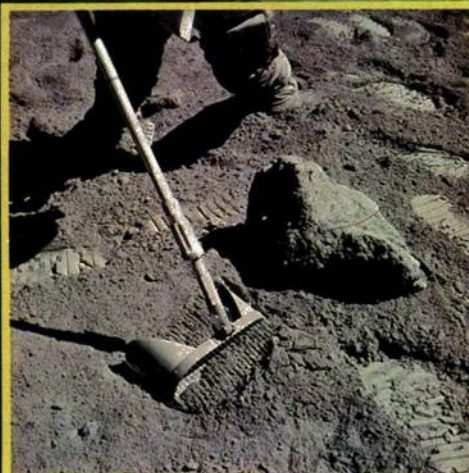
billion years ago the lava flows ceased. The maria were in place and looked much like we see them today. There are few dark maria on the far side of the Moon because the crust is thicker there than on the near side.

The five photographic satellites of the pre-Apollo Lunar Orbiter Program, which searched for Apollo landing sites in 1966 and 1967, inadvertently discovered a strange feature associated with the maria. The five orbiters experienced a change in speed as they passed over the maria: they slowed down over the maria and sped up after passing them. The cause of this — an apparent localized increase in the lunar gravitational field — implied that there were concentrations of mass in the maria.

These unexpected gravitational features, called mascons, indicate that the lunar crust was rigid enough to support the shallow, disklike maria as they formed. As lava spilled onto the lunar surface, the crust did not sink back to an isostatic equilibrium because the zone of



The bright rays of a small crater, west of Gagarin on the far side, have not yet succumbed to meteorite erosion.



"Gardening" by impacts produced the fine lunar regolith that clearly holds the footprints of Apollo astronauts.

Ray craters, such as 55-mile-wide Copernicus, are the only major features formed in the last 800 million years.

melting was too far below this cold crust to be deformed by the additional mass of the maria. The heavier basalts of the maria were forever locked into place above a sea of lighter crustal material.

The surface features of the maria reveal a history of volcanic as well as tectonic activity. The meandering trails of sinuous rilles, many of which have a circular pit at one end, were probably the channels through which lava once flowed into the basins. Parallel faults produced the straight rilles, a depressed area between the faults that geologists call grabens. Slight folding and faulting of the maria's surface layer caused the low "wrinkle" ridges that frequently form concentric rings on the maria plains.

If we could have seen the Moon at the end of the basin-filling period 3.1 billion years ago, we would have seen essentially the same Moon we see today. Only a few major ray craters like Tycho would be missing from the panorama, and it is likely that other ray systems, long since faded from view, would have been prominent.

Eternal Erosion

It is somewhat paradoxical that the next era of lunar evolution, the Eratosthenian Era, which spans fully half — 2.3 billion years — of the Moon's history, produced the least obvious changes in the Moon as viewed from Earth. Although small-scale volcanism continued for perhaps the first 500 million years of this era, the most profound changes were caused by small meteorites inexorably pelting the Moon. These impacts systematically pulverized and abraded the surface, producing craters and redistributing surface material vertically and laterally.

A new layer, called the regolith, was added to the Moon's surface. This layer is composed of fine-grained fragments as well as large blocks of bedrock excavated from the local area or thrown from great distances by the force of impacts. Small impacts produced soil breccias the same way the larger, basin-forming impacts created the highland breccias.

Surface photographs taken during the lunar missions show the result of these impacts. Almost everything looks rounded and subdued; no jagged peaks or sharp rocks can be found. Persistent impacting over a long period has eroded all but the most recent lunar formations.

The Copernican Era — the last 800 million years of the Moon's history — is arbitrarily benchmarked by the impact that caused the crater Copernicus and its magnificent ray system. Only the ray systems, created by the ejecta from the most recent impacts, distinguish this era from the preceding billion years. The rays associated with the crater Tycho, which is only 107 million years old, are a dominant visual feature of the Moon.

Two other ray craters — North Ray and South Ray — were focal points of the Apollo 16 mission in 1972. Studying these craters and their associated ejecta was a way of sampling lunar surface layers much deeper than core sampling could reach. These small craters are fairly recent: North Ray Crater is 50 million years old and South Ray Crater is only 2 million years old.

Yet these rays will fade too. Solar wind ions, cosmic rays, and micrometeorites will continue to erode the lunar surface. Although millions of years are required to wear off a layer a millimeter thick from the surfaces of lunar rocks, the rounded upper surfaces of rocks ejected from relatively fresh craters at several Apollo sites are proof of the inexorable processes taking place.

Seismic experiments carried out during the Apollo Program have given scientists a look at the internal

structure of the Moon. The lunar crust is roughly 40 miles thick on the near side and as much as 60 miles deep on the far side. Meteorite bombardment has covered the crust with a layer of rubble perhaps a mile deep in the highland areas and generally less than 20 yards deep on the maria. The uppermost part of this layer is the regolith.

The Moon has a thick mantle that is solid and rigid to depths of up to 500 miles, but the occurrence of moonquakes in the mantle indicates the presence of stress and deformation. A meteorite collision in 1972, recorded by seismic instruments left by Apollo astronauts, provided data demonstrating that there is a zone about 750 miles deep where the rocks must be at least partially molten.

The Moon's present seismic activity is very low. Moonquakes on the lunar surface only reach 2 on the Richter scale. A moderate-sized Fourth of July fireworks display gives off more energy than the whole Moon does in a year. These lunar disturbances are most prevalent when the Moon is closest to Earth and are thus related to the Earth's tidal forces. And, unlike earthquakes, moonquakes occur very deep in the interior.

Less is known about the core of the Moon. At 1300 Kelvins or higher, the core is at least partially molten; it accounts for the inner 150 to 450 miles of the Moon's radius. If the core is composed of iron sulfide, the larger dimension would be consistent with the known density of the Moon. However, if the core is nickel-iron like Earth's, the Moon's core would have to be much smaller than this.

Hints of Continuing Volcanism?

Given the immense thickness of the solidified lunar mantle and the lack of significant seismic activity, most scientists have concluded that lunar volcanism has not been possible for some time. Yet the detection of radon gas near the crater Aristarchus and around the edges of many of the circular maria demonstrates that the Moon, although cold and quiet, is not completely dormant. Sporadic venting of small quantities of gas along faults in these locations may raise dust that obscures features and causes red glows — two effects occasionally observed as Lunar Transient Phenomena by earth-based observers.

Our knowledge of the Moon has resolved many of the classic debates about its geological evolution. Even with the wealth of data from the Apollo missions, however, the old question of the origin of the Moon remains unanswered. Several competing theories have been proposed over the years, but none was confirmed by the Apollo data.

A new theory — the "collision-ejection" theory — has emerged in the last few years and has gained considerable acceptance. It proposes that a planetary body, roughly the size of Mars, collided with the early Earth and threw material from the mantles of both objects into space. This material quickly accreted and formed the Moon.

Does this theory, then, provide the missing piece that completes our picture of the Moon's evolution, from start to finish? It is too early to tell. Certainly such definitive answers will have to await man's return to the Moon. Since there are no lunar missions currently planned, these answers may have to wait a very long time.

Michael T. Kitt is a member of the Association of Lunar and Planetary Observers and director of the American Lunar Society, an organization devoted to amateur lunar studies. His last contribution, "A Rare View of Mare Orientale," appeared in the November 1985 issue.

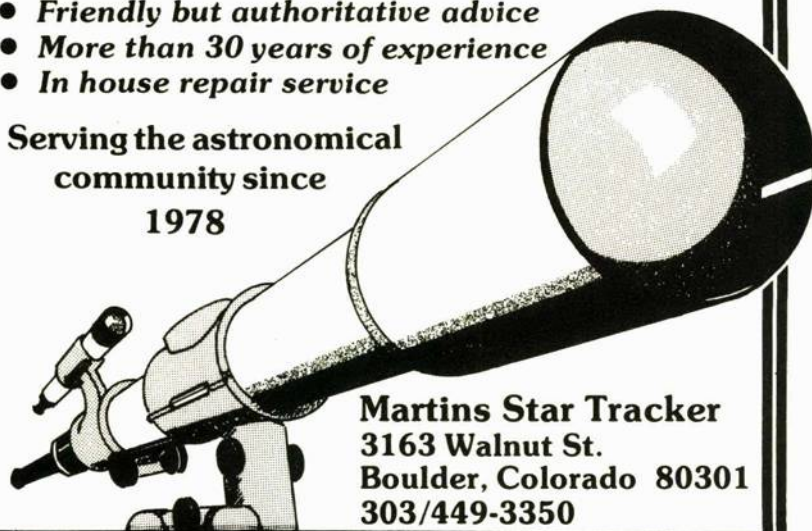
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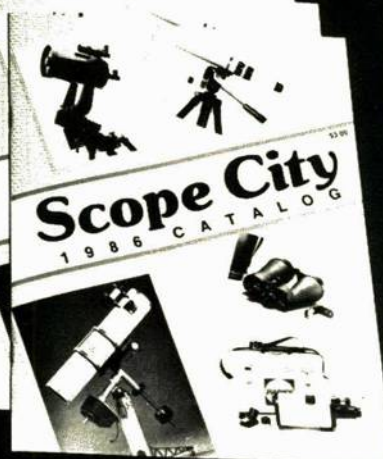
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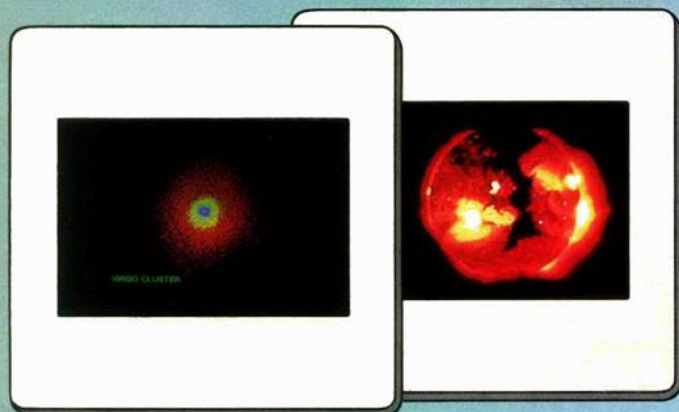
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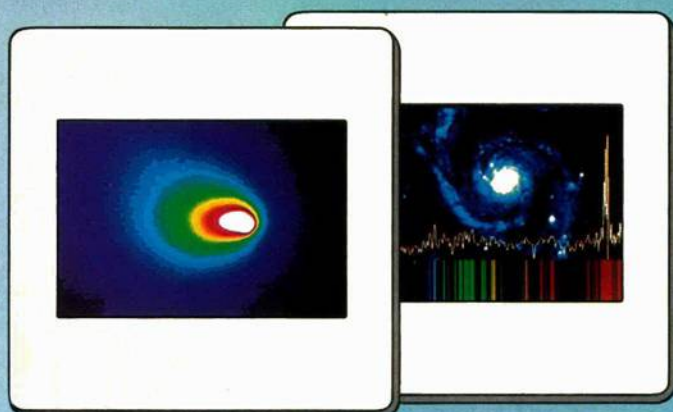
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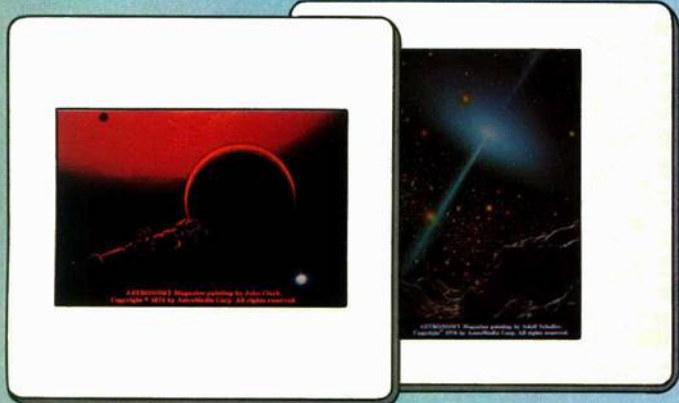
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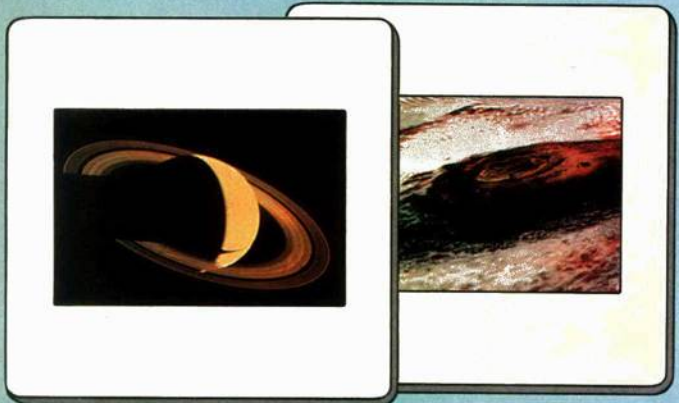
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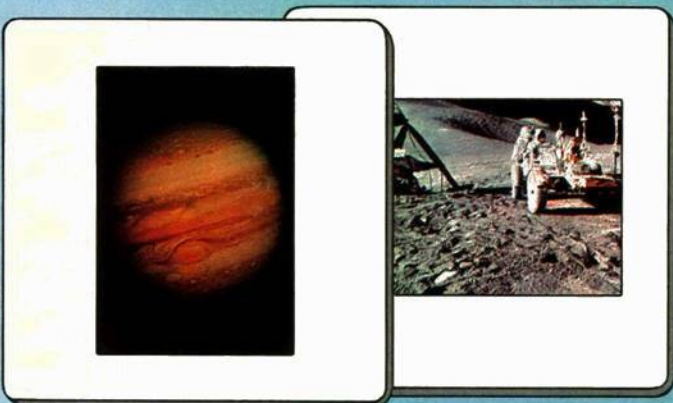
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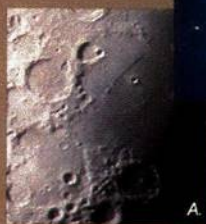
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- A. Lunar Craters photographed through the Bausch & Lomb 8" Schmidt/Cassegrain using eyepiece projection at an E.F.L. of over 32,000 mm!
- B. Galaxy M-51 taken by Dr. Stephen Kent of Harvard University with the Bausch & Lomb 8" Schmidt/Cassegrain and a C.C.D. Exposure time — 10 minutes!
- C. Galaxy M-31 taken by Jeff Peronto using a 300mm lens mounted piggyback on the Bausch & Lomb 8" Schmidt/Cassegrain. This photo is a 16 minute unguided exposure illustrating the superior accuracy of the Bausch & Lomb drive system.

When it comes to resolving Saturn's Cassini's Division, the New 8001 runs rings around the competition.



NGC-3132 is known as the "Eight-Burst Nebula" because of its complex multi-ring structure. In backyard telescopes it appears as a bright disk of nebulosity surrounding a 10th-magnitude central star. Photo by Jack B. Marling.

Vela

Vel
Velorum

Pyxis

Pyx
Pyxidis

Vela the Sails, a brilliant constellation containing more than four dozen naked-eye stars, lies square on the galactic equator in the thick of the southern Milky Way. To the south of Vela is the bright constellation Carina — the giant Eta Carinae Nebula lies just 3° south of Vela's southern boundary — and north of Vela lies the star-poor region dubbed **Pyxis** the Ship's Compass. All of these constellations were members of the antiquated star group Argo Navis, which was divided into separate constellations in the mid-eighteenth century.

One of Vela's most appealing objects is the bright planetary nebula **NGC-3132**. This object shines at photographic magnitude 8.2, and its central star glows at magnitude 10.1, which make this object one of the brightest planetary nebulae in the sky. To find NGC-3132, look 2.5° northwest of the 4th-magnitude star η Velorum. The nebula is located within several arcminutes of the Vela-Antlia border.

NGC-3132's appearance changes dramatically from telescope to telescope, though it is similar in many ways to the Ring Nebula in Lyra. In a finder scope only the central star is visible, while a longer-focus instrument like a 2-inch refractor shows a small, fuzzy disk of gray light surrounding the pinpoint star. A 6-inch scope at high power shows a broad, bright ring of nebulosity around the star, and some sections of the ring appear brighter than others. Astronomers have nicknamed NGC-3132 the "Eight-Burst Nebula" because its complex structure suggests a group of oval rings stacked on top of one another at differing tilt angles.

Curiously, the 10th-magnitude central star that lies in the ring's center isn't a true central star: a study conducted in 1977 showed that this is not the star illuminating

the nebulosity. Instead, a 16th-magnitude dwarf star, some $1.7''$ away from the 10th-magnitude sun, is thought to excite the gas to a state of fluorescence.

About 7° south and 1.5° east of the Eight-Burst Nebula is a little-known globular cluster designated **NGC-3201**. This object is large and bright, spanning $18.2'$ and glowing with the light of a magnitude 6.8 star. Unfortunately, it has received little attention from many Northern Hemisphere observers because of its southern declination. NGC-3201 is an extremely loose-structured globular that appears in a 6-inch telescope as a $5'$ -diameter clump of faint stars devoid of the rich central condensation characteristic of a typical globular cluster. The noted Southern Hemisphere observer E. J. Hartung described NGC-3201's stars as lying in "short curved rays like jets from a fountain." How many tiny stars can your telescope resolve in this unusual cluster during a night of particularly steady seeing and superb transparency?

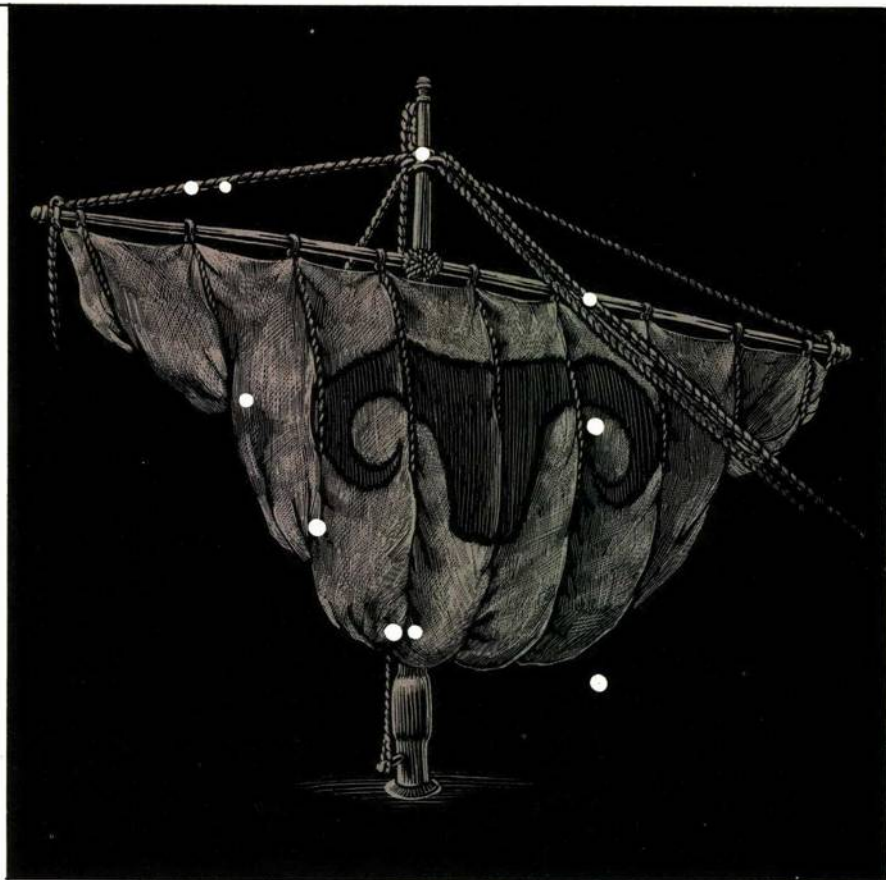
Continuing another 6° south we come to the large open star cluster **NGC-3228**, a sparse group of fifteen stars splashed across a brilliant stellar background some $18'$ across. Just visible to the naked eye as a 6th-magnitude patch of light, NGC-3228 is a fine object for observers with binoculars. Its brightest star shines at magnitude 7.9, while the rest dimly glow at 10th- and 11th-magnitude and fainter.

Another fine open cluster, **IC 2488**, lies

on the southern border of Vela 1° west of N Velorum. Much richer than NGC-3228, this group of seventy faint stars has a combined photographic magnitude of 7.4 over the cluster's $15'$ diameter. IC 2488's brightest stars are 10th-magnitude objects, so small telescopes show this cluster as a large haze peppered with a few resolved points of light. Ten-inch and larger scopes resolve several dozen stars and give a brighter overall image of the cluster, though they still show a milky nebulous veil strewn across the field of view.

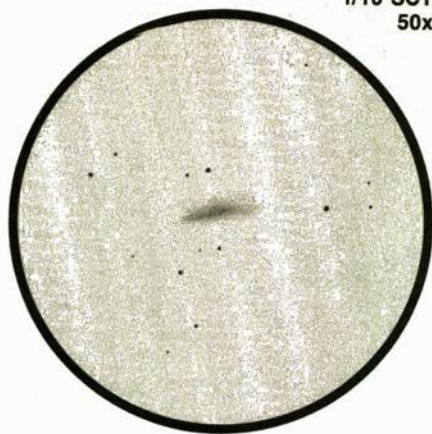
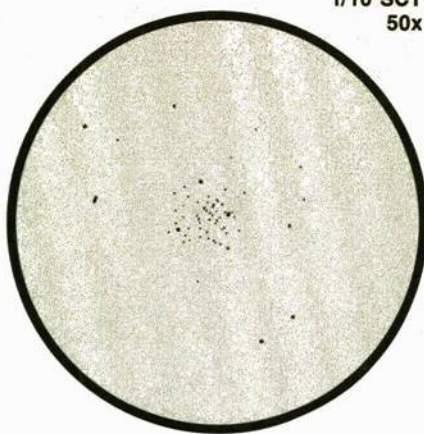
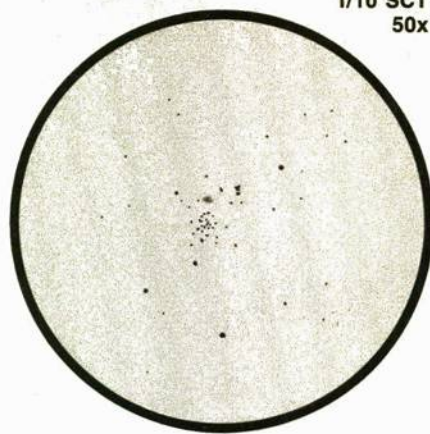
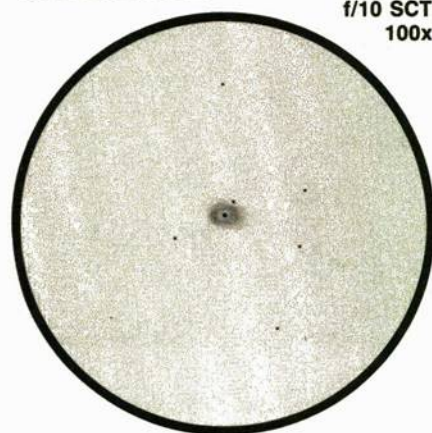
The second brightest star in Vela (only Gamma [γ] Velorum is brighter) is the double star **Delta (δ) Velorum**, which is a fine target for small telescopes. Located in the southwestern corner of Vela practically on the constellation's border with Carina, the star forms a triangle with bright stars Kappa (κ) and N Velorum. The primary star in this binary system is a magnitude 2.1 yellow luminary and the secondary is a yellowish magnitude 5.1 star. The two suns are separated by $2.6''$ in position angle 153° and are moving in a slow retrograde direction.

Just 2.5° northwest of Delta Velorum is the biggest, brightest open cluster in the constellation, **IC 2391**. This brilliant group of stars includes the magnitude 3.6 star Omicron ($\omicron$) Velorum and thirty others measuring nearly 1° across. The combined magnitude of all this light is 2.5, which means that IC 2391 is an easy naked-eye object even in relatively light-polluted



Keith Ward

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

NGC-26138-inch
f/10 SCT
50x**NGC-2659**8-inch
f/10 SCT
50x**NGC-2818**8-inch
f/10 SCT
50x**NGC-3132**8-inch
f/10 SCT
100x

Sketches by David J. Eicher

areas. Any optical aid shows the smattering of stars as a big, coarse group of bright white stars and numerous faint stars scattered over a rich Milky Way field that is somewhat reminiscent of the Pleiades cluster in Taurus. The "Southern Pleiades" is one of the finest fields for binocular and

small telescope viewers — especially star cluster devotees — and should be observed by everyone capable of seeing as far south as declination -53° .

Ten degrees north of the IC 2391 area is a smaller open cluster designated **IC 2395**. This is a rich cluster that contains forty stars in an area only 8' across, which yield an integrated magnitude of 4.6. Easily a naked-eye object under a dark sky, IC 2395 appears as a slightly fuzzy "star" due to its small size. In finder scopes and binoculars its nature is more apparent, and in a 6-inch scope at high power it shows as a patch of nebulosity intermixed with faint stars that gives the impression of spilled powdered sugar on black velvet. This object is even more impressive when viewed with large backyard telescopes, which show it as a rich, resolved collection of three dozen faint stars floating in Vela's sparkling Milky Way background.

The final open cluster in Vela is the pretty group **NGC-2547**, an assemblage of eighty stars inside a diameter measuring

20' across. A naked-eye object at magnitude 4.7, this star cluster offers a fine assortment of rings, chains, and arcs of stars.

Though the little constellation Pyxis offers less than its grandiose neighbor to the south, it does contain the open cluster **NGC-2818**. This object shines at magnitude 8.2 and spans some 9'; it contains forty faint stars in its gravitational grasp. A 13th-magnitude planetary nebula 40'' in diameter lies on the western edge of this cluster and is visible as a smudge of gray light at high power in backyard telescopes over 12 inches in aperture.

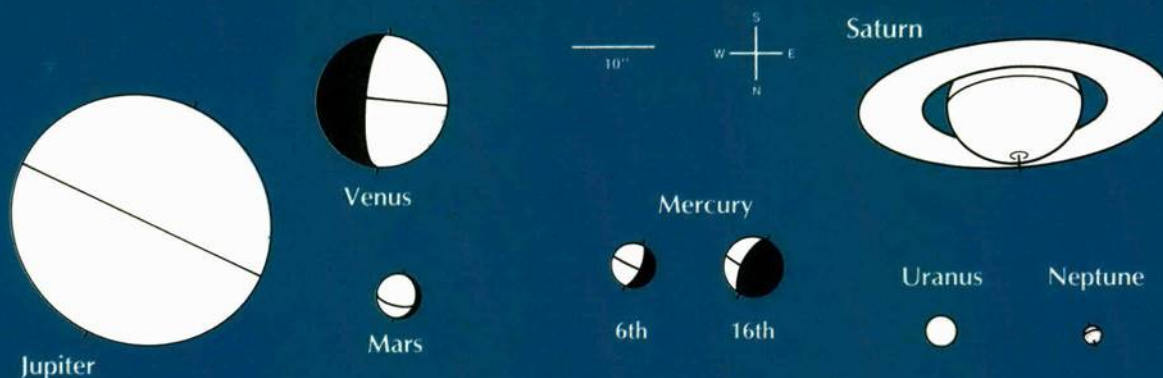
The fine galaxy **NGC-2613**, located in northern Pyxis some 3° southwest of a 6th-magnitude double star, concludes our survey of Vela and Pyxis. This spiral shines at magnitude 10.4 and covers 7.2' by 2.1', which make it a bright, elongated splash of nebulosity in small scopes. It is heavily obscured by dust in the Milky Way and would doubtlessly be more impressive if it lay well away from the plane of our galaxy.

Object	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
NGC-2547	○	8h 10.7m	$-49^\circ 16'$	4.7	20'	80	6.5
Al Vel	CV	8h 14.1m	$-44^\circ 34'$	6.4↔7.1	0.11d		
NGC-2613	§	8h 33.4m	$-22^\circ 58'$	10.4	7.2' x 2.1'		
NGC-2626	□ER	8h 35.6m	$-40^\circ 40'$	—	5'		
IC 2391	○	8h 40.2m	$-53^\circ 04'$	2.5	50'	30	3.6
IC 2395	○	8h 41.1m	$-48^\circ 12'$	4.6	8'	40	5.5
NGC-2659	○	8h 43.4m	$-32^\circ 39'$	9.2 _p	12'	80	12 _p
Delta (δ) Vel	★ ²	8h 44.7m	$-23^\circ 47'$	2.1, 5.1	2.6'		
T Pyx	IV	9h 04.7m	$-32^\circ 23'$	6.3↔14.0	7000:d		
NGC-2818	○	9h 16.0m	$-36^\circ 37'$	8.2	9'	40	11.3
IC 2488	○	9h 27.6m	$-56^\circ 59'$	7.4 _p	15'	70	10 _p
NGC-3132	■	10h 07.7m	$-40^\circ 26'$	8.2 _p	47''		10.1
NGC-3201	●	10h 17.6m	$-46^\circ 25'$	6.8	18.2'		
NGC-3228	○	10h 21.8m	$-51^\circ 43'$	6.0	18'	15	7.9

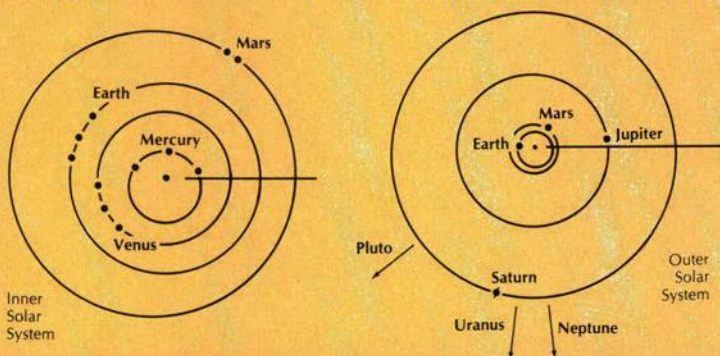
★ ²	Double Star
IV	Irregular Variable Star
CV	Cepheid Variable Star
○	Open Cluster
●	Globular Cluster
■	Planetary Nebula
□ER	Emission and Reflection Nebula
§	Spiral Galaxy

N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star



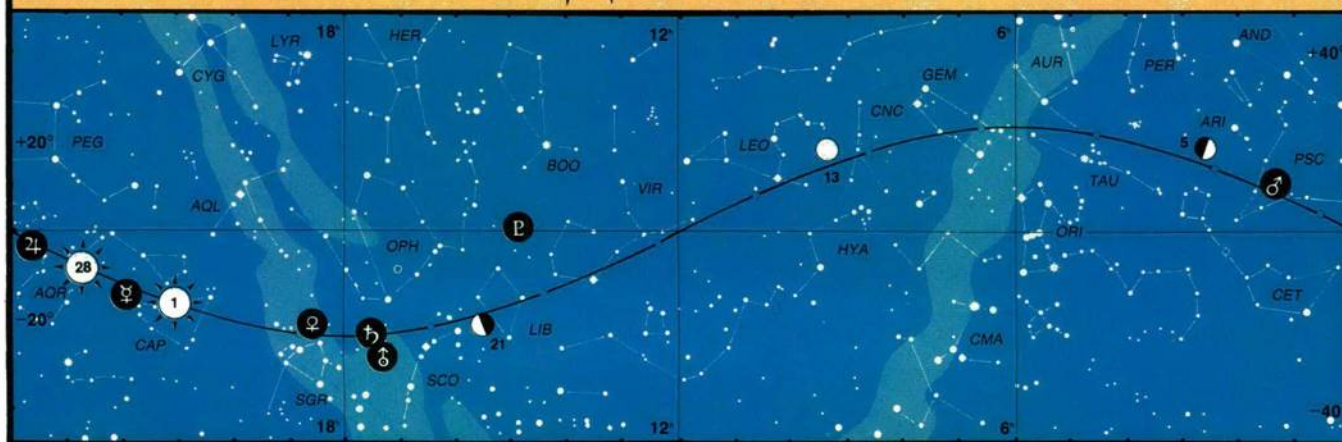


	Date	Mag.	Angular Size	% Illum.	Distance (AU)		Longitude:		R.A. (2000.0) Dec.	
					from Earth	from Sun	Heliocentric	Ecliptic		
Sun	1	-26.8	32.5'	—	0.985	—	—	311°35.2'	20h 56.9m	-17°15.8'
	15	-26.8	32.5'	—	0.988	—	—	325°46.0'	21h 52.8m	-12°52.5'
	28	-26.8	32.4'	—	0.990	—	—	338°51.9'	22h 42.5m	-8°11.0'
Mercury	♀ 1	-1.1	5.5"	88%	1.223	0.349	5°25.3'	324°58.1'	21h 51.1m	-14°28.0'
	15	0.0	7.7"	38%	0.869	0.308	87°06.9'	343°13.3'	22h 56.9m	-5°01.7'
	28	4.7	10.6"	1%	0.633	0.361	159°50.5'	338°24.7'	22h 34.9m	-4°56.8'
Venus	♀ 1	-4.3	21.0"	58%	0.796	0.720	184°23.4'	265°39.9'	17h 41.3m	-20°26.8'
	15	-4.2	18.5"	64%	0.900	0.722	206°58.5'	281°19.0'	18h 48.4m	-20°53.8'
	28	-4.2	16.8"	69%	0.995	0.724	227°49.0'	296°19.0'	19h 52.3m	-19°43.8'
Mars	♂ 10	1.0	5.6"	91%	1.676	1.492	58°21.7'	22°50.4'	1h 24.1m	9°07.1'
	20	1.1	5.4"	91%	1.758	1.505	63°44.9'	29°45.5'	1h 50.2m	11°45.2'
Jupiter	♃ 15	-2.1	34.0"	100%	5.783	4.959	2°10.6'	356°32.4'	23h 49.0m	-2°23.8'
Saturn	♄ 15	0.5	15.9"	100%	10.377	10.019	254°24.5'	259°45.5'	17h 15.9m	-21°20.0'
Uranus	♅ 15	5.7	3.6"	100%	19.668	19.192	263°18.4'	266°01.3'	17h 42.7m	-23°30.4'
Neptune	♆ 15	8.0	2.2"	100%	30.883	30.238	275°49.3'	277°23.7'	18h 32.0m	-22°13.4'
Pluto	♇ 15	13.7	0.1"	100%	29.423	29.698	218°03.7'	220°08.5'	14h 51.5m	0°51.0'



Moon Data

First Quarter.....February 5 at 16h21m
 Full Moon.....February 13 at 20h58m
 Last Quarter.....February 21 at 8h56m
 New Moon.....February 28 at 0h51m
 First Quarter.....March 7 at 11h58m
 Full Moon.....March 15 at 13h13m
 Apogee: Feb. 9 at 16h02m.....405,715 km
 Perigee: Feb. 25 at 15h54m.....363,799 km



Observers in North America and throughout the Northern Atlantic region enjoyed the annular solar eclipse on October 3. This photo shows the event near mid-eclipse as seen from Cody, Wyoming. It was taken with a 4-inch f/10 SCT, Kodachrome 25 film, and a 1/1000-second exposure without a filter. Photo by Dewey Vanderhoff.

Mercury

When Mercury appeared low in the west-southwestern evening sky at the end of January, it was beginning an apparition that reaches best visibility around the middle of this month. February 12 marks Mercury's greatest elongation, when the planet will be about 9° high in the southwest 45 minutes after sunset. (For a general view of Mercury's motion and elevations, see the diagram on page 52.)

This apparition is characteristically swift: 4° high on February 1, Mercury rises to its peak on the 12th and then vanishes from view by about the 22nd. Five days later it passes through inferior conjunction and up into the morning sky.

Telescopic viewing calls for a site with a low horizon to the west and southwest. Poor seeing will ruin the planet's tiny image, so use low to moderate magnifications — roughly 10x to 15x per inch of aperture. With clear evenings at a premium, have your equipment ready to go at a moment's notice.

Venus

Venus remains bright and prominent in the morning sky. Viewed with medium magnifications, its disk — featureless and white — spans about 20". Since January 15, when Venus passed greatest elongation, its phase has been "rounding out" and becoming gibbous in shape. If you find the glare dazzling, try viewing during twilight when the contrast between planet and sky is relatively low.

Mars

On February 15, Mars will lie 1.72 astronomical units (260 million kilometers) from Earth. As a result the planet has an apparent diameter of only 5.5" — smaller than the apparent sizes of many lunar craters. The ruddy planet is then so small and distant that viewing its surface features amounts to glimpsing vaguely-defined shadows on a tiny ochre ball.

Fortunately Mars is high enough in the early evening so, if the night offers steady seeing conditions, try your highest power eyepieces.

Minor Planets

1 Ceres (magnitude 8.4) lies in southern Ophiuchus. On the 10th and 11th, it will be passing about 1.5° south of M-9, an 8th-magnitude globular cluster 9' in diameter. Ceres' positions:

1st: 17h 05m 23s, -19° 34.8'

10th: 17h 18m 31s, -20° 01.7'

20th: 17h 32m 16s, -20° 26.8'

28th: 17h 42m 30s, -20° 43.9'

Ceres rises around 3:30 a.m. local time on February 15.



Satellites of Jupiter

1h00m UT

1 CJEG	• • • • •	16 JECG	• • • • •
2 CJEG	• • • • •	17 ECIJ	• • • • •
3 CEIGJ	• • • • •	18 CGEJI	• • • • •
4 CGJEI	• • • • •	19 CGIJE	• • • • •
5 CGIJE	• • • • •	20 CGEJI	• • • • •
6 CEGJI	• • • • •	21 CEIJG	• • • • •
7 CEIJG	• • • • •	22 CJIEG	• • • • •
8 CJEG	• • • • •	23 CJEG	• • • • •
9 JIECG	• • • • •	24 CEJG	• • • • •
10 EIJC	• • • • •	25 GEJI	• • • • •
11 GJIC	• • • • •	26 GIJCE	• • • • •
12 GIJEC	• • • • •	27 GJIC	• • • • •
13 GEJIC	• • • • •	28 EIJGC	• • • • •
14 EIJGC	• • • • •		
15 JIEGC	• • • • •		

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



2 Pallas (9.2) is moving eastward in Serpens Caput. Its positions:

1st: 15h 46m 22s, 3° 19.2'
10th: 15h 56m 47s, 4° 45.7'
20th: 16h 06m 49s, 6° 38.3'
28th: 16h 13m 31s, 8° 20.2'

Pallas rises around midnight on the 15th.

3 Juno rises too close to sunrise to be visible this month.

4 Vesta (8.3) is in Pisces, to the northwest of the star Alrisha. Its positions:

1st: 1h 17m 18s, 1° 45.9'
10th: 1h 28m 45s, 3° 16.4'
20th: 1h 42m 16s, 4° 57.1'
28th: 1h 53m 36s, 6° 17.2'

Vesta sets around 10 p.m. local time on the 15th.

15 Eunomia (10.1) is moving retrograde in Sextans, about 20° south of Regulus. Its positions:

1st: 10h 49m 26s, -4° 32.4'
10th: 10h 42m 28s, -4° 34.9'
20th: 10h 33m 33s, -4° 22.1'
28th: 10h 26m 05s, -4° 01.5'

At opposition on February 24, Eunomia is visible all night this month.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet

coordinates are for the epoch 2000.0.)

Jupiter

This is the last good month for viewing Jupiter before it sinks toward the Sun. By February 28, it will be only 9° high in the southwest 45 minutes after sunset and distortions from bad seeing will worsen your views of the planet.

Although Jupiter is nearing conjunction with the Sun (March 27) and is near maximum distance from Earth, it still spans over 33". This gives it the largest apparent diameter of any planet now, so don't pass up chances to look at it. To enhance the visibility of the Jovian "surface" features (cloud tops, actually), hold a light blue or pink photo filter over the eyepiece while you look through it. Switching rapidly from one filter to the other will produce interesting changes in the details you perceive.

Saturn

Saturn is another planet that benefits from viewing with filters. Even with filters, however, you'll find the amount of detail visible on Saturn much less than that visible on Jupiter. Part of this comes from high-altitude haze in Saturn's atmosphere but, more significantly, the planet itself is simply less active than Jupiter. Because its details appear washed out, Saturn may require somewhat denser filters than Jupiter did. Try pairing a Wratten #25 dark red filter with a #47 (blue) or #58 (green).

Above: One of the most prominent dark nebulae visible from the Northern Hemisphere is Barnard 92, an opaque patch masking part of the star cloud M-24. In this photograph another dark nebula, Barnard 93, is visible to the left of B92. Photo by Scott Hicks, who used a 12.5-inch f/4.8 reflector, Konica 1600 film, and a 20-minute exposure.

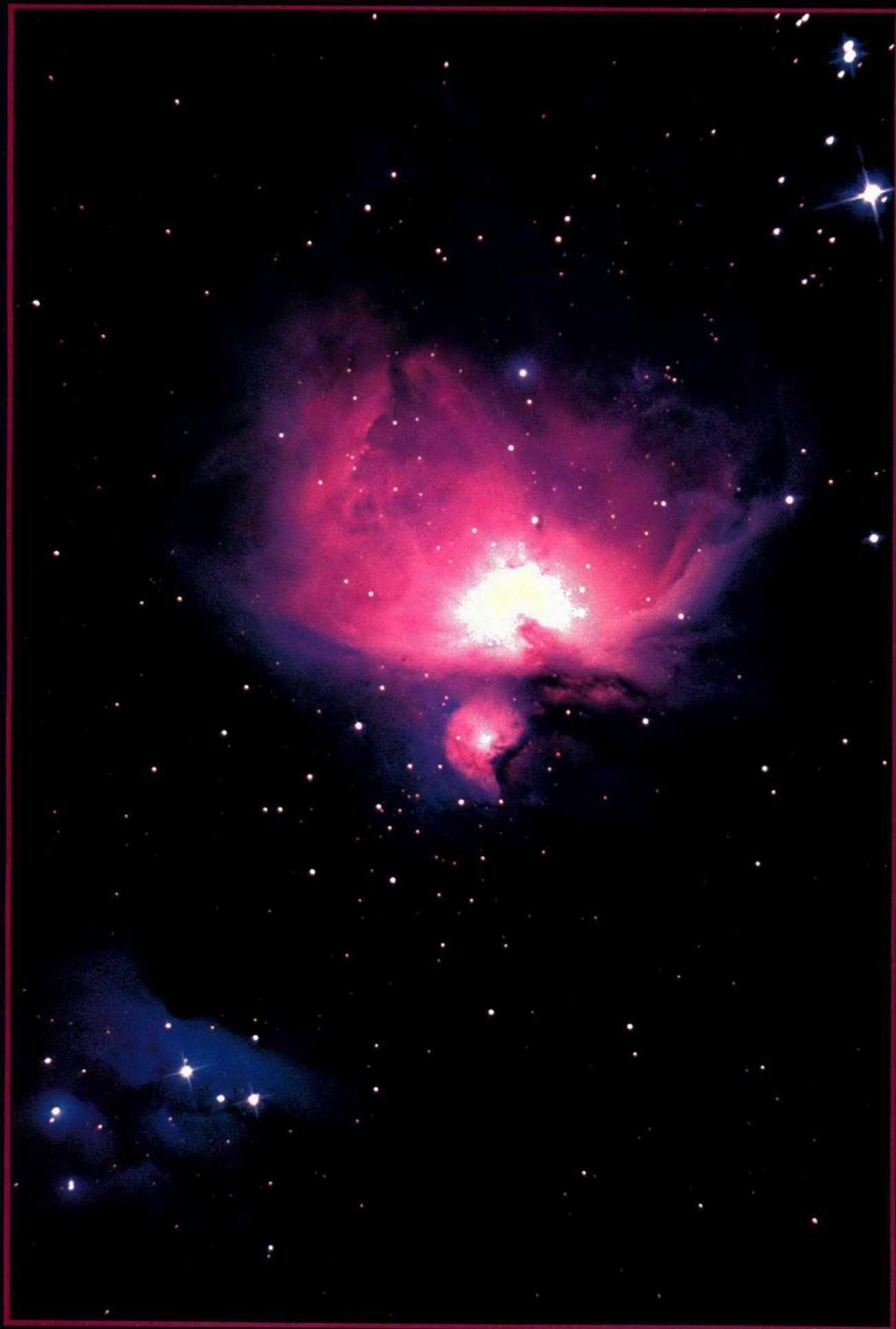
Opposite page: Scott Hicks' spectacular photograph of the Orion Nebula nets him this month's \$100 "Best Astrophoto" award. The photograph is a 25-minute exposure on Konica 400 ISO film, made with a 12.5-inch f/4.8 reflector.

Uranus

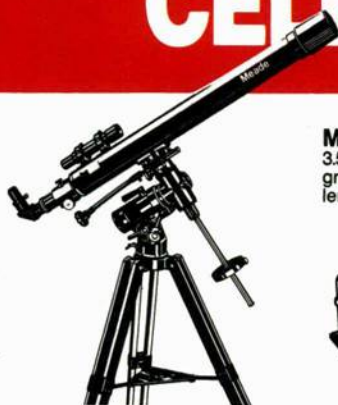
Though it lies on the Sagittarius-Ophiuchus border, Uranus rises early enough in the morning during February to be about 20° high 45 minutes before sunrise. Antares is the easiest place to start searching: Uranus lies 2° south and 18° east of Antares. Uranus is also 5° east-northeast of magnitude 3.3 Theta (θ) Ophiuchi. Look for a 6th-magnitude bluish-green object showing a 3.6" disk.

Neptune

The simplest way to find Neptune is to locate magnitude 2.8 Lambda (λ) Sagittarii, the star at the top of the Teapot's lid. Neptune lies 3° north and 4 minutes of right ascension (about 1°) east from this star and has an 8th-magnitude grayish disk 2.2" across.



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- | | | | |
|---------------------------------|-------|--------------------------------|-------|
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